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Losses Due to the Sheep Blowfly.

*By M. J. Mackerras, M.Sc., M.B.**

1. Introduction.

The chief sheep-growing countries of the world are as follows:—

Country.	Number of Sheep (1934).	Cut in Pounds per Head (1934).
Australia	113,048,000	9·0
United States of America	52,210,000	8·4
Soviet Union	51,925,000	2·7
India	43,279,000	2·0
Argentina	39,330,000	9·4
Union of South Africa	35,011,000	6·3
New Zealand	28,649,000	9·3
United Kingdom	24,944,000	4·6

The numbers of sheep are from the *Commonwealth Year-Book* (1936), and the cuts per head have been calculated from figures given by the Imperial Economic Committee (1937). It may be noted that two other countries cut more than 9 lb. per head, namely, Hungary with 10.0 lb., and Germany with 9.2 lb.

In Australia, South Africa, New Zealand, and the United Kingdom, the blowfly causes serious losses. In the United States of America, the problem appears to be rather different, in that the wound-infesting flies *Cochliomyia macellari* and *C. hominivorax* cause much trouble, and attention is mainly directed to them; however, *Lucilia sericata, L. cuprina* (which causes so much trouble in Australia), and *Phormia regina,* occur, and cause myiasis in sheep. No records are at present available as to the position in the Soviet Union, but the above figure includes goats, and sheep raised are mainly coarse-woolled types cutting less than 3 lb. per fleece, so that blowfly attack is probably not serious. MacLeod (1937) states that *Lucilia sericata* occurs in Russia, but it has not been recorded as attacking sheep there. He also states that sheep myiasis apparently is not a serious problem in Europe, although *Lucilia sericata* occurs and has been reported as striking sheep in Holland.

We have no information about the position in India, but species of *Lucilia* occur and wound-infesting flies are common. It appears that the Indian sheep are mainly coarse-woolled and relatively insusceptible.

With regard to the Argentine Republic we have no estimates as to incidence of strike or losses, nor do we know the species of flies

* An officer of the Division of Economic Entomology.

concerned, but the problem appears to be rather similar to that in Australia. Lieut.-Colonel Dunlop Young of London very kindly forwarded some information obtained from Dr. Beyro, Director of Veterinary Services, Buenos Ayres. His remarks may be summarized as follows:—

> Blowfly strike on sheep is common in the eastern part of the country, especially in the provinces of Corrientes and Entre-Rios; going west and south it becomes less and less frequent. (These districts are about the same latitude as New South Wales.) The breeds of sheep raised are mainly Lincoln, Romney Marsh, and Merino (Argentine and Australian types), then Downs, Corriedales, &c. The fly causes most trouble, where the Merino dominates. High rainfall and hot climate favour the spread of strike.

2. The Problem in Various Countries.

(i) *Great Britain.*

Records of maggot infestation may be found in writings of the sixteenth century, but it is only very recently that any attempt has been made to estimate the annual loss sustained. The incidence of strike is surprisingly high, considering the small wool production per head and the relatively cold climate. *Lucilia sericata,* however, thrives during the summer, when rains and dews render the sheep particularly liable to body strike, which is the commonest type in the United Kingdom.

In North Wales the counties of Anglesey, Caernarvon, Denbigh, and Flint carry over a million sheep, according to Maldwyn Davies (1934). This author considered that, although the loss by death was small, there was a considerable loss of time and considerable expenditure in attending to struck sheep, especially in a bad year when 30 to 40 per cent. of a flock might be struck.

In Scotland, it is the considered opinion of sheepmen that the pest is gradually becoming worse and involving country previously untroubled by the sheep fly. Haddow and Muirhead Thomson (1937) state that in a flock of 1,000 sheep the owner lost 81 by death from strike in one year. The incidence of strike varies greatly from year to year, and the following figures have been given for experimental flocks:—

Morison (1937).—Incidence 12 per cent.

Miller (1935).—Incidence 15 to 20 per cent.

Ratcliffe (1935).—Incidence 34 per cent. in 1933; 27 per cent. in 1934.

MacLeod (1937) states that the incidence in a mixed flock near Stirling for the month of June, 1935, was as follows:—

Breed.	Number of Sheep.	Number of Strikes.	Percentage.
Corriedale	16	8	50
Lincoln	15	4	28
Romney Marsh	30	5	17
Shropshire	14	2	14
Half-bred and Greyface	29	2	7
Shetland	20	0	0

Ratcliffe (1934), by means of a questionnaire sent to sheep farmers in various parts of Scotland, obtained some information regarding the cost of the sheep fly to the industry in 1933. The estimates were very variable, ranging from nil up to £300. The figures given include the value of animals which died, the estimated depreciation in market value of affected animals, and the cost of dips and dressing.

Size of Flock.	Estimated Loss.
	£
400 ewes, plus lambs	40
1,000 ewes, plus lambs	104
1,400 ewes, plus lambs	150–170
900 sheep	72
6,500 sheep	300
900 ewes, plus lambs	113
2,400 sheep	20
500 ewes, plus lambs	11
1,400 sheep	5
400 ewes, plus lambs	19
1,200 sheep	25
1,700 sheep	82

Omitting those in which the number of lambs is not stated, we have figures from six properties, which, if added together, give the loss on 14,100 sheep as £504. This is roughly £35 per 1,000, or 8d. a head. MacLeod (1937) estimated the loss at 1s. per head of adult stock.

In 1934, there were 24,944,000 sheep in Great Britain (*Year-Book* 1936); calculated at the rate of £35 per 1,000 the loss would be approximately £873,000.

(ii) *South Africa.*

In South Africa, Smit (1931) estimated the annual loss for wool alone to be £100,000. This does not include loss by deaths, nor the increased expenditure incurred in dealing with the struck animals. He states that there were 40,000,000 sheep in the Union in 1929, and the average infestation was over 10 per cent. *Lucilia sericata* is a cause of myiasis.

(iii) *New Zealand.*

In New Zealand, Gilruth (1907) recorded *Lucilia sericata* as infesting sheep, and Miller (1922) collected some data on the losses sustained. The estimated annual loss by deaths was about 1 per cent.; if the sheep were not crutched this might rise to 5 per cent. or 10 per cent. One observer stated that the mortality among Lincoln hoggets in a wet season was 20 per cent., and among Romneys 10 per cent. In a dry season the figures would be 10 per cent., and nil, respectively.

(iv) *Australia.*

In Australia, efforts have been made from time to time to estimate the loss sustained through the sheep blowfly. Froggatt (1914) estimated that the damage done in New South Wales in the year 1912 amounted to £1,000,000, with a similar loss in Queensland. McLeod and Holme,

in a prize essay on the sheep blowfly problem extracted by Cooper (1913), estimated the loss in New South Wales as £377,700 per annum, but this is probably too conservative an estimate. Froggatt and Froggatt (1916) quote figures from the *Pastoral Review*, giving the estimated loss of sheep by deaths due to blowfly strike in New South Wales for 1914:—

Total Number of Sheep.	Estimated Loss.	Percentage Loss.
37,999,542	481,318	1.2

Johnston (1921) stated that the annual loss by death of sheep due to fly attack in Queensland had been estimated at 5 per cent. In 1920, the sheep population in Queensland numbered 17,000,000, and at the above rate the total deaths would have amounted to 850,000 animals.

Froggatt and Froggatt (1916) also give figures for the cost of crutching on four properties in various parts of New South Wales. Rather less than half these sheep were wigged as well, so that the cost of crutching alone would be lower.

Number of Sheep.	Total Cost.
35,097	£228
11,604	64
29,451	188
6,120	45
83,272	£525

Cost of treatment approximately 1½d. per head.

McCulloch has recently made careful estimates of the costs of crutching and jetting. In 1935, he found that crutching cost 1¼d. per head and jetting less than ½d. per head. Later (McCulloch, 1938), he found that three jettings cost approximately the same as one crutching, i.e., 1½d. per head or slightly more.

I. M. Mackerras (1930), putting the matter in a slightly different way, estimated that 3½ per cent. of the cost of production of wool was due to the blowfly. The same author (1936) summarized the damage due to blowfly as follows:—

1. Loss of sheep. Usually the mortality is not high, but occasionally in bad outbreaks losses of up to 28 per cent. of young ewes in a flock have been reported.
2. Loss of struck wool. This has been estimated as up to a pound weight or more of fleece in bad cases.
3. Deterioration of the whole fleece due to tenderness or break. The fact that, following a heavy year of natural and experimental strikes, 85 per cent. of the fleeces of our experimental flock were classed as tender, is sufficient indication of the seriousness of this condition.
4. Struck sheep do not thrive. Lambs neither grow nor fatten well, older sheep lose condition, ewes probably will not mate readily, and rams may possibly become temporarily infertile. It is difficult to estimate the actual monetary losses due to these effects, but they certainly interfere with proper routine management of a flock.

5. The costs of handling and treatment. These vary in different districts, but have been roughly estimated at about ½d. per strike.

6. The costs of preventive measures. These, of course, can only be included if, and to the extent that they are not out-weighed by savings due to their use.

Belschner (1937) has collected actual book figures for the loss of animals and expenditure due to the blowfly from three stud and five flock properties in New South Wales. The following is his summary:—

Property.	Total Sheep.	Losses in Wool and Sheep.	Expenditure on Crutching, Jetting, Dressings and Labour.	Total Cost.	Total Cost per 1,000 Sheep on Property.
		£		£	£
1. Stud ..	40,000	6,200	£2,272 (13·6d. per head) ..	8,472	212
2. ,, ..	20,000	3,062	£1,302 (15·5d. per head) ..	4,364	218
3. ,, ..	20,000	2,340	£668 (8·0d. per head) ..	3,008	150
4. Flock ..	20,000	1,541	£412 (4·9d. per head) ..	1,953	93
5. ,, ..	20,000	396	£425 (5·1d. per head) ..	821	41
6. ,, ..	20,000	162	£226 (2·7d. per head) ..	388	19
7. ,, ..	20,000	125	£132 (1·5d. per head) ..	357	13
8. ,, ..	21,000	62	£107 (1·2d. per head) ..	169	8

On stud properties the average cost of the fly was £198 per 1,000 sheep, while on flock properties it was £35 per 1,000 sheep. It is interesting that the latter is the same as the average for Scotland (p. 99).

In 1934 there were 113,048,000 sheep in Australia; of these 53,327,000 were in New South Wales. Calculated on the basis of £35 per 1,000, the blowfly cost New South Wales £1,866,000 in 1934. If the rate is applied to the whole of Australia, which may or may not be justifiable, the tremendous figure of £3,856,000 is obtained. This is approximately the same as the estimate of £4,000,000, which is widely quoted as the loss in Australia. How that figure was arrived at has not been published. If these losses could be eliminated, an appreciable saving in production costs would be obtained, and there is no indication that the increase in quantity of wool and carcasses produced would affect the price of either adversely.

The high incidence of strike in a small experimental flock of aged merino ewes in Canberra clearly shows what may happen, when protective measures are not adopted. *Lucilia cuprina* caused over 90 per cent. of these strikes.

Year.	Number of Sheep.	Number Struck.	Percentage Struck.	Number of Strikes.	Percentage Incidence of Strike.
1933–34	125	87	70	207	165
1934–35	118	76	64	127	107
1935–36	127	75	59	141	111
1936–37	124	80	65	146	117

These figures can be greatly reduced by applying known preventive measures and a considerable saving effected thereby. But the statistics set out earlier in the report show that the cost of applying these measures is considerable. The advantage of the Mules operation or selective breeding for a plain-bodied flock is that a considerable degree of permanent protection is obtained, without appreciably increasing the cost of production.

3. References.

Belschner, H. G., 1937.—A review of the sheep blowfly problem in New South Wales. Dept. Agric. N.S.W., Sci. Bull. No. 54.

Davies, W. Maldwyn, 1934.—The sheep blowfly problem in North Wales. *Ann. App. Biol.*, **21**: 267-282.

Froggatt, W. W., 1914.—Sheep maggot flies in Australia. *Bull. Ent. Res.*, **5**: 37-39.

Froggatt, W. W., and Froggatt, J. L., 1916.—Sheep maggot flies. No. 2. N.S.W. Dept. Agric., Farmers' Bull. No. 110.

Gilruth, J. A., 1907.—The Sheep Maggot. N.Z. Dept. Agric., Divn. Vet. Sci., Bull. No. 12.

Haddow, A. J., and Muirhead Thomson, R. C., 1937.—Sheep myiasis in south-west Scotland with special reference to species involved. *Parasit*, **29**: 96-116.

Imperial Economic Committee, 1937.—Wool production and trade. H.M. Stationery Office, London.

Johnston, T. Harvey, 1921.—The sheep maggot-fly problem in Queensland. *Q. Agric. J.*, **15**: 244-248.

Mackerras, I. M., 1930.—Recent development in blowfly research. *J. Coun. Sci. Ind. Res.* (Aust.), **3**: 212-219.

Mackerras, I. M., 1936.—The sheep blowfly problem in Australia. *Coun. Sci. Ind. Res.*, Pamphlet No. 66.

MacLeod, J., 1937.—The nature, epidemiology and control of sheep myiasis in Britain. *J. Comp. Path. and Therap.*, **50**: 10-32.

McLeod, A. E., and Holme, J. B., 1913.—Prize essay extracted by W. F. Cooper. The sheep maggot fly pest in Australia. The Cooper Laboratory for Economic Research, Watford, England.

McCulloch, R. N., 1935.—Jetting and crutching for the control of blowfly strike. *Agric. Gaz. N.S.W.*, **46**:

McCulloch, R. N., and Hockley, J., 1938.—Sheep blowfly control by jetting. *Agric. Gaz. N.S.W.*, **49**: 131-135.

Miller, D., 1922.—Sheep maggot-flies. *N.Z. J. Agric.*, **24**: 335-336.

Miller, W. C., 1935.—Some observations on the prevention of blowfly attack in sheep. *Scot. J. Agric.*, **18**: 226-231.

Morison, G. D., 1937.—Some results of trapping the sheep blowfly. *Scot. J. Agric.*, **20**: 123-134.

Ratcliffe, F. N., 1934.—(Communicated by James Ritchie.) Sheep maggot flies in Scotland. *Scot. J. Agric.*, **17**: 249-260.

Ratcliffe, F. N., 1935.—Observations on the sheep blowfly (*Lucilia sericata* Meig.) in Scotland. *Ann. App. Biol.*, **22**: 742-753.

Smit, B., 1931.—A study of the sheep blowflies of South Africa. 17th Report, Director Veterinary Services and Animal Industry, Union of South Africa.

——, Year-Books of the Commonwealth of Australia, 1936, and preceding.

A Preliminary Note on the Experimental Reproduction of Bovine Pleuro-pneumonia.

*By A. D. Campbell, B.V.Sc.**

Summary.

1. Typical contagious bovine pleuro-pneumonia can readily be produced in susceptible cattle either by exposing them to highly-atomized culture or by introducing culture into a small bronchus by means of a catheter. For dealing with large numbers of animals the atomization technique is preferable.

2. The experimentally-produced disease is in all respects identical with the naturally occurring disease and is infectious to suspectible cattle.

3. As the remaining postulate of Koch has now been fulfilled, Nocard and Roux's organism can be regarded definitely as the cause of the disease.

4. These findings give us a method for testing induced resistance which is regarded as superior to subcutaneous inoculation of cultures.

1. Introduction.

In 1898, Nocard and Roux first demonstrated the presence of their organism in the pleuritic exudate and lungs of cattle affected with contagious bovine pleuro-pneumonia. Later workers have consistently found it associated specifically with the disease, but have been unable wholly to satisfy Koch's postulates; for, with the possible exception of Daubney (1932), no one has succeeded in reproducing the disease with cultures, or, indeed, even with pathological fluids. There has therefore been some speculation whether it may not be only an organism secondary to a hitherto undiscovered filterable virus.

There have, of course, been some attempts to reproduce the disease. Cameron's (1906) method, later attempted by Turner, Campbell, and Dick (1935), which consists of deeply injecting pleuritic exudate or culture into the inferior peritracheal areolar tissue, sometimes produces a severe specific exudative pleuritis with heavy deposition of fibrin, but pulmonary involvement is limited to pressure collapse and pleural lymphangitis. Daubney's (1932) technique, later modified by Turner, Campbell, and Dick (1935), which consists of injecting specifically infected emboli† into the jugular vein, produces only infarcts which do not resemble characteristic lesions of pleuro-pneumonia. Nocard and Leclainche (1903) credit Chauveau with having successfully transmitted the disease from a sick to a healthy animal by connecting their heads by means of a long linen tube. Inspired by this, Nocard and Roux (1901) carried out some suggestive attempts at artificial reproduction by passing atomized culture into sacks surrounding the heads of cattle. Of five animals, four underwent merely a transient pyrexia but were apparently immunized; the fifth, after a pyrexial course, died a month later and presented lung lesions that were said to resemble the first stage of pleuro-pneumonia. However, the experiments were not regarded by a sceptical world as convincing, and all authorities have united in stating that it is impossible to reproduce the disease experimentally.

* An officer of the Division of Animal Health and Nutrition who is located at the Melbourne Laboratory of the Division in the grounds of the Veterinary Research Institute of the University of Melbourne.

† Small pieces of pneumonic lesion (Daubney) and broken-up clotted blood cultures (Turner, Campbell, and Dick).

The result is that the incubation period is little understood, there is some doubt about the etiological significance of the organism, and no satisfactory method exists of testing the resistance of animals. The last point is of extreme importance in Australia, especially northern Australia, where control largely depends upon vaccination. Information is urgently needed on the efficacy and duration of vaccination, and its rapidity of onset.

The object of this paper is to describe briefly the progress made at this Laboratory in filling these gaps in our knowledge.

2. Experimental Reproduction.

(i) Inhalation Technique.

In spite of the unconvincing experiments of Nocard and Roux (1901), the late Dr. J. A. Gilruth, then Chief of the Division, had strongly suggested a re-examination and perfection of their technique. This we have done, with extremely satisfactory results.

Technique.—Since pleuritic exudate is often difficult to obtain in quantities when required, we use cultures in B.V.F.-O.S. medium (Turner, Campbell, and Dick, 1935), in which virulence is retained for comparatively long periods. Amounts of 600 ml. are atomized by means of a commercial paint-spray gun (Arnold manufacture) and air at a pressure of 40 lb. per square inch (from a compressor or cylinders). The nozzle is adjusted so that the atomization is completed within 15 minutes, the resulting very fine fog-like suspension of droplets being directed into a suitably closed loose-box approximately 12 feet by 12 feet by 10 feet, in which up to eight cattle are placed. The animals are then removed to open stalls, regular temperature and clinical observations taken, and blood collected at regular intervals for serological examination by means of the complement-fixation test (Campbell and Turner, 1935) and sometimes the agglutination test.

Results of Infection.—Complement-fixing antibodies become detectable in low titre as early as 6 or 7 days after the animals are exposed to the infective mist, or may be delayed until the 10th or 12th day. The titre thereupon rapidly rises, e.g., from iv/10* on the 6th or 7th day to iv/1280 or more on the 9th or 10th. The subsequent behaviour depends upon the type of infection that develops, which can be of three types.

During this work, 80 head of cattle, mostly heifers from 2½ to 3 years old, have been subjected to atomized culture, with the following results.

(*a*) *Acute Cases.*

Thirty-three, i.e., 41 per cent., developed clinical pleuro-pneumonia. The first sign is hyperpyrexia, which may occur rapidly or may develop during several days; morning temperatures may reach 106°F. Clinical signs of disease are later in occurring than the complement-fixation reaction and usually are obvious between the 12th and 18th day, occasionally as late as the 27th.

* See Campbell and Turner (1936) for explanation of this method of expressing titres.

It must be admitted that many of these animals show little sign of illness other than pyrexia, roughened coat, distressed look in the eyes, anorexia, accelerated respirations with a tendency to use the abdominal instead of the thoracic muscles, and the characteristic "moist" cough. The relatively mild clinical picture is undoubtedly due largely to the animals being kept stalled and under conditions of hospitalization. If they are briskly chased and forced to run, they quickly show signs of acute respiratory distress and anoxaemia: the respirations become stertorous, the mouth opened, the tongue protruded, and the membranes cyanosed; the beasts cough repeatedly in the characteristic, repressed, and apparently painful manner. The respirations become noticeably of the abdominal type, with the ribs fixed, and if exertion is pushed still further the animals come to a standstill, with legs and head extended, profuse nasal discharge and salivation, and mouth wide open. Such animals usually die (Fig. 1) or become progressively weaker and emaciated until destruction is necessary in the 3rd or 4th week.

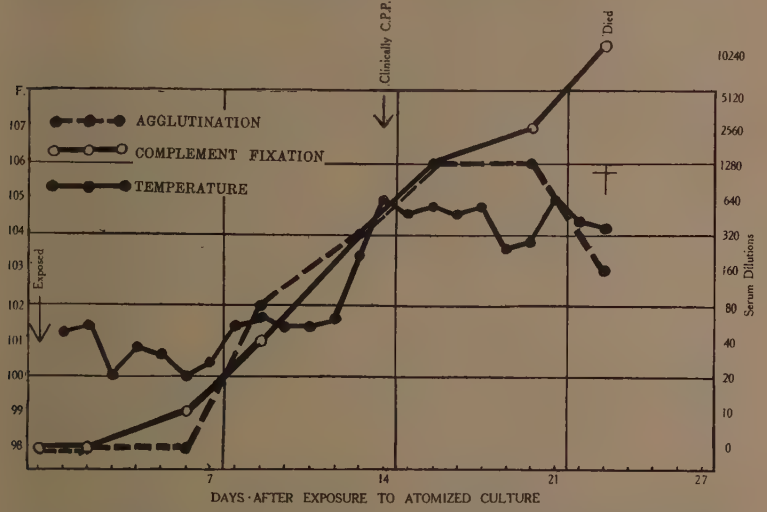

FIG. 1.—Clinical and serological chart of an unvaccinated animal infected with fatal pleuro-pneumonia by exposure to atomized culture. The early appearance of antibodies, antedating clinical signs, and the tendency for the agglutinin titre to fall after clinical signs appear, are shown.

Before the onset of clinical signs of disease, the complement-fixation reaction rapidly rises to the order of iv/1280; with the development of the disease, the titre rises to the order of iv/10120 or iv/20240, at which it persists until death or slaughter.

When autopsied, these animals generally show the following pathological picture. The thoracic cavities contain many litres (up to 10 l.) of pleuritic exudate, the pleurae covering the parietal and visceral surfaces show the characteristic lymphangitis and are usually blanketed with a thick fibrinous deposit. This frequently involves the pericardium and occasionally the epicardium, and there may be exudation into the pericardial sac.

The anterior and posterior mediastina are filled with a sero-fibrinous exudate. The associated bronchial and mediastinal glands are greatly enlarged and oedematous. The involvement of the lungs is often bilateral, but extensive hyperacute lesions usually only involve one lung. However, smaller lesions may be found in either the diaphragmatic, cardiac, or apical lobe of the other lung.

On cutting the hepatized portions of the lungs, the pathological changes typical of pleuro-pneumonia are found. There is extensive interlobular lymphangitis with sero-fibrinous exudation into the alveolar tissue, thrombosis of blood vessels, and the characteristic "marbling". Often, at the periphery of a lesion, bands of intralobular lymphangitis extend out into the apparently normal parenchymatous tissue. Some lobules may show a certain degree of sero-fibrinous infiltration in the alveolar tissue, and bronchial catarrh.

Cultural examinations carried out during autopsy reveal the presence of the specific organism in the pleuritic exudate, lung lesions, the associated lymph glands, heart blood, and all viscera.

Fulminating Type.—One of the most acute and fulminating cases of experimental inhalation pleuro-pneumonia occurred in a calf, born of a cow that had been vaccinated at the tip of the tail. Neither the calf nor its mother were exposed to any risk of natural infection and were kept in strict isolation. When three months old it was exposed with its mother to atomized culture. Its serum at that time gave a negative complement-fixation reaction.

Twenty-four hours after exposure it was reported to be very lethargic and weak, and died 24 hours later, i.e., 48 hours after exposure.

The right thoracic cavity was completely filled with straw-coloured pleuritic exudate. The costal and visceral pleurae and the pericardium were completely covered with a thin fibrinous veil. The myocardium showed sero-fibrinous oedema.

The whole of the right diaphragmatic lobe, and the dorsal portion of the right cardiac lobe, were hepatized, and the remaining portion of the cardiac and the whole of the apical lobe were affected with pressure collapse and subpleural lymphangitis. On cutting the lesion it was found to be typical of pleuro-pneumonia but of an extremely hyperacute type. The lesion was bright-red in appearance, but consolidation was not complete. The intralobular lymphatics showed extensive lymphangitis. The alveolar tissue was infiltrated with sero-fibrinous oedema. Arteries and veins were extensively thrombosed. The left lobes of the lungs, except for sub-pleural lymphangitis involving the latero-dorsal portion of the diaphragmatic lobe, were unaffected. Cultural examination revealed the presence of the specific organism in pure culture in pleuritic exudate, the lung lesions, and the associated lymphatic glands.

(*b*) *Subacute, Non-clinical Cases.*

Forty-one animals, i.e., 52 per cent., developed a milder type of disease, and would probably have escaped detection if sera had not been submitted to the complement-fixation test. They showed only mild and transitory signs of illness, generally a rise of morning temperature to 103° or 104°F., and very little distress when forced to exert themselves.

The complement-fixation reactions are similar to those of the more acutely affected animals, but the end titre rarely exceeds iv/5120 and, having persisted at its maximum for several weeks, drops back and persists at about iv/640 or a little greater for a long period.

Pathological changes found in these animals are not so extensive as in acute cases. Usually, a longer interval between exposure and autopsy has elapsed. Characteristic lesions are present in the lungs, but, owing to the lapse of time, have usually passed the acute stage; they are more often undergoing resolution, or may consist of either small or large areas becoming sequestrated. There is usually some degree of pleuritis.

Occasionally, resolution has progressed to such an extent that the affected area has been replaced by fibrous tissue, but even in some of these fibrous areas small sequestra containing viable organisms may be found. Cultural examination always revealed the presence of the organism in the resolving and sequestrating lesions. The associated thoracic glands are enlarged and may also contain the causal organism.

Atypical Cases.—Two of the 80 animals, exposed to infection in different experiments, behaved atypically. Their serological behaviour suggested pulmonary infection, but they showed no clinical signs. Both were slaughtered 30 days after exposure, and no evidence of lung lesions could be found. However, the mediastinal and bronchial glands were enlarged and oedematous. Cultural examination of these glands revealed the presence of the specific organism of pleuro-pneumonia. These two cases are extremely interesting, for in our earlier work (Campbell and Turner, 1936) we recorded three similar instances from a natural outbreak of the disease. With those cases, as with the artificially produced cases, no evidence of lung lesions could be found: yet a significant complement-fixation reaction was obtained.

(*c*) *Refractory Cases.*

Six animals, *i.e.*, 7.5 per cent. were classed as refractory; they gave only a transitory complement-fixation test of low titre (up to iv/80), showed no signs of illness, and when examined *post mortem* after various periods revealed no traces whatever of pleuro-pneumonia.

Discussion.

Of 80 animals subjected to experimental infection by the inhalation technique described, 74 (92.5 per cent.) revealed, either after death or slaughter from 4 to 8 weeks after exposure, conclusive evidence of having developed a specific thoracic infection. Of these, 33 (41.25 per cent.) developed clinical pleuro-pneumonia associated with extensive acute lesions. Forty-one (51.25 per cent.) developed only a mild, subclinical infection but revealed definite lesions when examined *post mortem*; they were comprised of 34 (42.5 per cent.) that had resolving or encapsulated lesions, 2 (2.5 per cent.) that showed merely involvment of thoracic lymph glands, and 5 (6.25 per cent.) that had healed lesions. Six animals (7.5 per cent.) proved refractory. This distribution probably depends partly upon the interval elapsing between infection and autopsy. It is interesting to compare these results with the natural-infection experiment carried out on unvaccinated cattle by Campbell and Turner (1936) at Townsville, when out of 65 animals, 22 (33.9 per cent.) developed clinical pleuro-pneumonia, 26 (40 per cent.) the subclinical form of the disease, and 17 (26.1 per cent.) were

quite refractory. The higher proportion of refractory animals found at Townsville may be due to a more wide-spread natural resistance in Queensland (although the animals came from parts of the State known to be free of the disease for many years) or to the superiority of experimental over natural infection. It is worth while taking this opportunity of stressing the relatively high proportion of subclinical infections with pleuro-pneumonia that occur under conditions of exposure to natural infection. Cattle in an epidemic are not sharply divided into clinical cases and naturally resistant animals. An important proportion develop the disease without showing observable signs other than a serological response, yet they may, and often do, develop into chronically infected animals with infective sequestra.

(ii) Catheterization Technique.

Although earlier attempts to produce pleuro-pneumonia by intra-tracheal inoculation have not been encouraging, it was decided to carry out further experiments. Histological evidence suggests that the primary lesion is in the terminal bronchioles: attempts were therefore made to introduce culture as far down the bronchial tree as possible.

Technique.—Three head of cattle were thrown, kept under restraint, and their mouths opened as wide as possible with a mechanical gag. During an inspiratory movement, the end of a long rubber catheter of 7 mm. external diameter was passed through the larynx and pushed onwards down the trachea until it impacted in a small bronchus. A funnel was attached to the outer end of the catheter and culture poured down. In each case 15 ml. of a four-day-old, second-generation subculture was introduced; No. 92 received it alone, No. 93 received after it 10 ml. of broth, and No. 94, 85 ml. On another occasion, three more animals were treated; No. 146 received 5 ml. of a similar culture washed down with 20 ml. of broth, No. 147 received 1 ml. of culture with 24 ml. of broth, and No. 148, 2.5 ml. of culture with 22.5 ml. of broth.

Results.—In the first experiment, all three animals commenced to undergo a rise of body temperature 48 hours after the injection, which within 7 or 8 days reached a maximum of from 105°F. to 105.6°F. More characteristic clinical signs of pleuro-pneumonia, such as typical cough, respiratory distress, &c., develop from the 8th to 10th day. All three gave a strongly positive complement-fixation reaction on the 8th day after inoculation. The animals ran a severe hyperacute course; No. 93 was killed on the 8th day, while the other two died, No. 94 on the 17th day and No. 92 on the 27th day. Clinically, all were typical cases of acute pleuro-pneumonia.

Autopsy Finding.—No. 93, which was killed 8 days after inoculation, gave a typical picture of early hyperacute pleuro-pneumonia, with a small amount of pleuritis and exudate. No. 94 was a typical acute case with about 1 l. of exudate, thick fibrinous deposit on the right costal pleura and lung and hepatisation of almost the whole right lung. No. 92 was a typical advanced acute case, with from 3 to 4 l. of characteristic exudate and hepatisation of the whole right lung. In all cases, pure cultures were recovered from exudate, lungs, heart blood, and viscera.

In the second experiment, two of the animals, Nos. 147 and 148, showed a thermic response five days after inoculation which reached a

maximum of 105°F. between the 11th and 12th days. A strong complement-fixation reaction was given by each animal from the 7th day onwards. Characteristic clinical signs were apparent on the 10th day; both animals ran a severe hyperacute course. No. 147 died 28 days after inoculation and at autopsy showed extensive pleuro-pneumonic involvement of the thoracic organs. No. 148 was destroyed on the 40th day and at autopsy extensive pleural adhesions were found as well as a large sequestrating lesion in one of the diaphragmatic lobes.

No. 146 showed no marked thermic response, nor were clinical symptoms noted. A strong complement-fixation reaction was given from the 7th day to the 40th, when the animal was destroyed. A large sequestrated lesion about 8 x 10 x 8 cm. was found in one of the diaphragmatic lobes.

In No. 147 pure cultures were recovered from pleuritic exudate, lung lesions, heart blood, and viscera; in Nos. 146 and 148, only from the lung lesions and associated thoracic glands.

Discussion.

The above experiments, successful in six cases out of six, demonstrate conclusively that acute, typical, pleuro-pneumonia can be reproduced by the aid of cultures of Nocard and Roux's organism when introduced into small bronchi by the above technique. The disease produced is in every way similar to that occurring in natural outbreaks: the clinical and pathological pictures are identical; there is the same tendency to occasional subclinical infections and to sequestration; the serological and bacteriological findings are the same. As will be discussed below, the artificially reproduced cases are highly infectious to susceptible cattle.

The main objection to the technique is that animals have to be restrained in the recumbent position, each animal has to be individually handled, the passing of the catheter and the carrying out of the inoculation is not easy; finally, the technique is after all highly artificial and does not so nearly approach the natural method of droplet infection as the atomization technique, which is relatively simple and adapted for treating animals in batches. Where only small numbers of animals are to be inoculated, as for teaching purposes, it seems to be very satisfactory.

These results contrast with the earlier attempts of Campbell and Turner (1935, 1936) at Townsville. Five ml. of culture, followed by 10 ml. of saline (2 cases) or up to 40 ml. of bronchial washings from acute cases (9 cases) were introduced into the trachea by a rubber tube passed through the larynx. All animals developed positive complement-fixation reactions but none developed clinical signs of pleuro-pneumonia. The two animals that received culture were autopsied eleven weeks later, when one showed extensive old pleural adhesions and the other, which had previously been shown to be susceptible to subcutanous inoculation, showed no alterations. Those treated with bronchial washings of an acute case showed a gangrenous type of inspiratory pneumonia, contaminated with *B. pyocyaneus,* and with a varying degree of pleuro-pneumonic extension from the infected lesion. Whether the superior results obtained in Melbourne are partly ascribable to the experimental animals' susceptibility or to the passing of a narrow catheter until it impacts in a small bronchus, we cannot say.

The only successful attempt at reproducing the acute disease by simple intratracheal introduction was recorded by Daubney (1932) who, using several mils of filtrate of pleuritic exudate introduced by a clean syringe and inoculating needle through a trocar passed through the wall of the trachea, succeeded in one out of twenty attempts in producing typical pleuro-pneumonia.

3. Infectivity of Artificial Pleuro-pneumonia.

Our first indication that the experimental disease was contagious was given by a calf which was delivered seven days after its mother had been exposed to artificial infection. The mother at this time was not showing any serological reaction or clinical symptoms. However, five days after the birth of the calf, i.e. 12 days after exposure, clinical signs began to appear, and during the next 23 days the animal went through a very severe and fatal infection. The calf was allowed to remain with the mother until her death, but its diet was supplemented by bucket feeding. Seven days after the death of the mother, that is when it was five weeks old, and 30 days after the mother first became ill, the calf was reported to be lethargic and refusing to drink its milk. From this time until death, 18 days later, it exhibited very severe clinical symptoms of pleuro-pneumonia. At autopsy, typical acute pleuro-pneumonia was found involving the lung, pleurae, mediastina, and pericardium. The pleural cavities contained several litres of exudate. Cultural examination revealed the presence of the organism in the lung lesion, pleuritic exudate, thoracic lymph glands, heart blood, and the abdominal viscera. Assuming that the calf became infected when the mother first showed signs of illness, the maximum incubation period could not have been greater than 30 days; it may have been less. During the whole period of observation, the mother and calf were strictly isolated from other cattle.

In addition, three cattle were placed in contact in a small yard with the first three that had been infected by the intratracheal-catheterization technique. As stated above, these three inoculated animals developed hyperacute pleuro-pneumonia and eventually succumbed to the infection. The three contact animals also developed symptoms of hyperacute pleuro-pneumonia, and eventually died. At autopsy very acute and extensive pleuro-pneumonia was found.

Incubation Period.—These three animals were allowed contact from the commencement of the experiment. Assuming that infection occurred at some time between the beginning of the experiment and the death of the last animal 27 days later, then the incubation period of each case is between 21 and 48, 23 and 55, and 30 and 58 days respectively. The incubation period of the calf that became infected from its mother was between 30 and 35 days, probably 30 days. Three observations on infection from natural cases, accumulated by Campbell and Turner (1936) at Townsville, gave incubation periods of 29, 34, and 41 days, respectively, which is quite of the same order as the above instances of infection from experimental cases. It would seem that the incubation period for contact infection is between 3 and 6 weeks. With artificial infection by the atomization technique, the incubation period lies between 9 and 27 days, by the catheterization technique from 48 hours to 10 days.

4. Influence of the Age of Subcultures on the Severity of the Resulting Lesions.

On reviewing the clinical and pathological data collected over a number of experiments in which the same strain of the organism has been used as an infecting agent, it is apparent that a comparatively recently isolated and early subculture of the specific organism must be used to produce acute pleuro-pneumonia.

There is also some evidence that an attenuation occurs with increasing age of a culture, independently of the attenuation that follows repeated subculturing. Also, it appears that age attenuation can be often overcome by carrying out a few rapid subcultures. With attenuated strains the severity of clinical symptoms decreases, and at autopsy the pathological changes are found to be less extensive and show a greater tendency to become sequestrated.

5. References to Literature.

Cameron, S. S. (1906).—*J. Dept. Agric. Vict.*, **4**: 489.

Campbell, A. D., and Turner, A. W. (1936).—Coun. Sci. Ind. Res., (Aust.), Bull. **97**.

Daubney, R. (1935).—*J. Comp. Path.*, **48**: 83.

Daubney, R. (1932).—Rept. Dept. Agric. Kenya, 286.

Nocard, E., and Roux, &c. (1901).—Cited by Nocard and Leclainche (1903).

Nocard, E., and Leclainche, E. (1903).—"Les maladies microbiennes des animaux," **1**: 475 (Masson et Cie: Paris).

Turner, A. W., and Campbell, A. D. (1936).—*Aust. Vet. J.*, **13**: 183.

Turner, A. W., Campbell, A. D., and Dick, A. T. (1935).—*Aust. Vet. J.*, **11**: 63.

Contagious Bovine Pleuro-pneumonia :
A Report on the Use of New Antigens for the Complement-fixation and Agglutination Tests.

*By A. D. Campbell, B.V.Sc.**

Summary.

1. The preparation of a new antigen for the diagnosis of bovine pleuro-pneumonia by the complement-fixation test is described.

2. The new culture antigen replaces the original Ebert and Peretz antigen formerly used by us.

3. It is easier to prepare, is more constant in its properties, and has a higher antigenic value and sensitivity.

4. Cattle exposed to atomized culture react between the 6th and 10th day, and when acutely affected may give complete fixation in dilutions as high as 1 in 20480. Chronically affected beasts are readily detected.

5. The preparation of a new antigen for the agglutination test is also described.

6. The agglutination test is, however, far less sensitive than the complement-fixation test even during the clinical phase, is negative in chronically affected animals, and is therefore of relatively little value.

1. Complement-fixation Test.

Campbell and Turner (1936) have published a detailed account of the technique of performing the complement-fixation test for the diagnosis and control of contagious bovine pleuro-pneumonia.

The antigen used was prepared from pleuritic exudate after the method described by Ebert and Peretz (1928). However, pleuritic exudate from cases of pleuro-pneumonia is not always readily obtainable; in addition, further experience has shown that individual samples are not always satisfactory and that the antigenic titre of different antigens may vary considerably. We have been able to overcome these difficulties successfully by applying the principle of the original Ebert and Peretz antigen to centrifuged cultures.

Preparation of Culture Antigen.

The causal organism of pleuro-pneumonia is grown at 37.5°C. in B.V.F.–O.S.† usually in amounts of 8-10 litres, for a period of fourteen days.

The culture is then passed at approximately 150 ml. per minute through a Sharples super-centrifuge revolving at a speed of 40,000 revolutions per minute. The deposited organisms are washed from the inside wall of the bowl with 150–200 ml. of glass-distilled water. The turbidity of the aqueous suspension is adjusted to Brown's No. 6 turbidity standard by the addition of more glass-distilled water. By means of a boiling brine bath the standardized suspension is kept at boiling point for ten minutes, it is then removed, allowed to cool, and made isotonic by the addition of 0.85 g. of pure sodium chloride per 100 ml. of suspension. It is then filtered through Whatman No. 1 filter paper, and finally 0.25 g. of carbolic acid crystals are added to every 100 ml. of fluid.

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† Campbell and Turner (1936).—Coun. Sci. Ind. Res., (Aust.), Bull., 97: p. 74.

The antigen is now ready for titration in parallel with a stock antigen. It is titrated against 2½ M.H.D. of complement with several strongly positive and several negative sera. In addition a saline series is included to test its anti-complementary properties.

If the above titration demonstrates that the antigenic titre is 8 to 10 times greater than the anti-complementary titre, then additional parallel tests on a large number of positive and negative sera are made with both antigens in a dilution containing five antigenic units. These tests determine sensitivity and specificity. Finally, before a new antigen is used in the routine test, a parallel test of the sera to be tested on one particular day is undertaken, a dilution of five antigenic units of each antigen being used as a dose. The results are compared, and if complete agreement is obtained the new antigen can then replace the old.

By the above method of preparation and subsequent antigenic test, we have always succeeded in obtaining antigens of exceptionally high titre, sensitivity, and specificity. The antigen is of such titre that it can usually be used in a dilution of 1 in 20 or greater, whereas the anti-complementary properties are negligible.

It is interesting to record here that boiling the organism in distilled water is essential in preparing an antigen of high value. Saline suspensions, or even boiled saline suspensions from the same batch of medium, are highly anti-complementary, and their antigenic value is always less than half that obtained from the boiled distilled-water suspension.

Complement-fixation Reactions with the New Culture Antigen.

(*a*) *Experimental Animals.* — When animals are subjected to atomized culture, detectable complement-fixing antibodies first appear between the 6th and 10th day (Fig. 1). The reactions obtained at these periods are of diagnostic titre, and by the time the animals are exhibiting clinical symptoms from 5 to 20 days later, complete fixation of 2½ M.H.D. of complement is obtained in exceptionally high serum dilutions (1 in 5120 to 1 in 20480). If the lung lesions have become sequestrated, these high complement-fixing values persist for a considerable time. However, if resolution takes place without sequestration of affected areas, the complement-fixation titre slowly drops back to about iv/80 to iv/160,* and there persists for a considerable time.

(*b*) *Field Outbreaks.*—Experience with outbreaks in Victoria, South Australia, and Western Australia have conclusively demonstrated the reliability of the new antigen. A remarkable correlation of the test with autopsy findings has been obtained, which demonstrates its superiority to the earlier pleuritic-exudate antigen.

Early in 1937, an outbreak of pleuro-pneumonia occurred in a herd of 128 bullocks depastured in one of the northern areas of Victoria. This herd was trucked to Melbourne and slaughtered under supervision, and a blood sample of each animal collected. Thoracic organs regarded as pathological by the lay inspectors were sent to the laboratory for examination. The pathological findings, cultural findings, and complement-fixation results of each beast from which these organs were obtained are shown in Table 1.

* See Campbell and Turner (1936) for an explanation of this method of expressing titres.

TABLE 1.

Animal No.	Pathological Findings.	Cultural Findings.	Complement-Fixation Serum Dilutions.			
			1/10.	1/20.	1/40.	C.S
4	Very small sequestrum; several small fibrous areas	−	−	−	−	−
6	Early sequestrating lesion, 8 x 8 x 6 øm.	+	++++	++++	++++	−
7	One small sequestrated lesion	Culture not done	++++	++++	++++	−
12	Small old sequestrated lesion	+	++++	++++	++++	−
20	Very doubtful early small lesion	Not done	+	±	−	−
25	Small sequestrated lesion and adhesions	+	++++	++++	++++	−
26	Very doubtful small early lesion	Not done	−	−	−	−
41	Early active large lesion	+	++++	++++	++++	−
42	Hyperacute lesion involving whole of one diaphragmatic lobe	+	++++	++++	++++	−
44	Doubtful small resolving lesion	−	−	−	−	−
45	Doubtful resolved lesion	−	−	−	−	−
48	Large sequestrated lesion	+	++++	++++	++++	−
50	Extensive hyperacute lesion	+	++++	++++	++++	−
51	Large old sequestrated lesion	+	++++	++++	++++	−
52	Sequestrated lesion 1 cm. in diameter	+	++++	++++	++++	−
63	Sequestrated lesion 0·5 cm. in diameter	Not done	++++	++++	++	−
73	Small sequestrated lesion 0·5 cm. in diameter	−	++++	++++	++++	−
74	Reported as normal, no specimen submitted for examination	No sample	++++	++++	++	−
76	Hyperacute lesion ..	+	++++	++++	++++	−
78	Small recovered lesion ..	−	−	−	−	−
86	Very early lesion, one lobule affected	+	++++	++++	++++	−
92	Small sequestrated lesion 0·5 cm. in diameter	−	++++	++++	++++	−
93	Adhesions only ..		−	−	−	−
94	Small sequestrated lesion 1 cm. in diameter	+	++++	++++	++++	−
95	Small sequestrated lesion, mediastinal lymph glands enlarged	+	++++	++++	++++	−
96	Adhesions		−	−	−	−
98	Large sequestrated lesion; extensive adhesions	+	++++	++++	++++	−
107	Large sequestrated lesion; extensive adhesions	+	++++	++++	++++	−
110	Two small sequestrated lesions	+	++++	++++	++++	−
113	Adhesions		−	−	−	−
116	,, ...		−	−	−	−
117	,, ...		−	−	−	−
120	Small sequestrated lesion with adhesions	+	++++	++++	++++	−

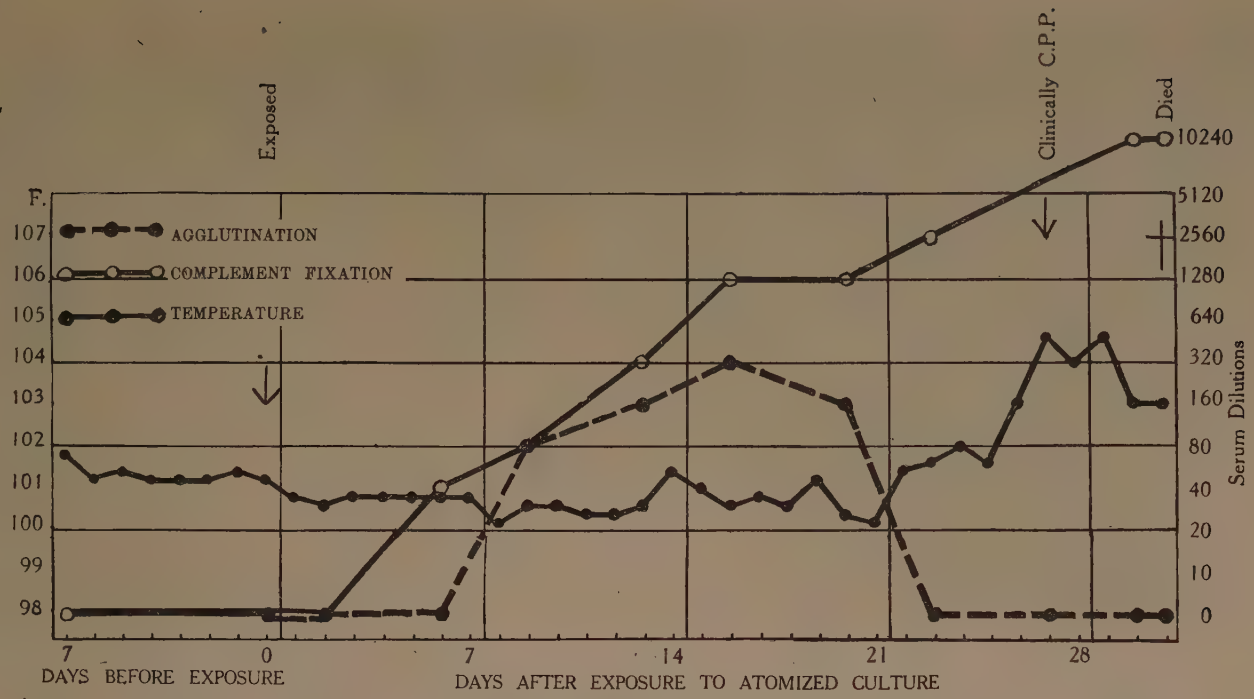

FIG. 1.—Clinical and serological chart of an unvaccinated animal infected with fatal pleuro-pneumonia by exposure to atomized culture. The early appearance of antibodies before clinical signs are obvious, and the transient nature of the agglutinin response, which has disappeared even before clinical signs appeared, are shown.

It is apparent from the above that, in Nos. 4, 44, 45, and 78, a negative complement-fixation reaction was obtained, although somewhat doubtful lesions were found in the lungs. In all these instances it was impossible to isolate the specific organism, and we are therefore justified in assuming that the lesions were not due to pleuro-pneumonia.

In one case (No. 74), where there were allegedly no apparent lesions, a positive complement-fixation reaction was obtained. However, this specimen was not submitted to us for examination, and possibly there may have been a small early lesion deep in the parenchymatous tissue of the lung, which could have been easily missed by the stock inspector collecting the specimens; alternatively, there may only have been a thoracic-gland infection (Campbell, 1938).

In No. 86 an extremely early lesion was found limited to one lobule of the lung; nevertheless, a very strong complement-fixation reaction was given by the corresponding serum sample. This result demonstrates the sensitivity of the test in detecting very early incubating cases.

The lungs of several animals (Nos. 63, 73, and 92) contained small resolving or very small sequestrated lesions, and the corresponding serum of each gave a very strong complement-fixation reaction; however, it was impossible to demonstrate the presence of the specific organism by cultural methods. Apparently the organism had died out.

The above complement-fixation results, combined with the pathological and cultural findings on the 128 head of bullocks, as well as results of other outbreaks in South Australia and Western Australia, demonstrate (*a*) the superiority of the culture-antigen, and (*b*) the use of the complement-fixation test in diagnosis and the control of pleuro-pneumonia.

Campbell and Turner (1936) attempted to indicate how the complement-fixation test, using the pleuritic-exudate antigen, might be applied by administrative officers to the control of the disease. They recommended certain control measures and indicated the type of complement-fixation reactions that would be obtained in an infected herd. As the result of greater experience, particularly following an extensive use of the new antigen, which is much more sensitive and yields higher titres, they have since found that certain modifications are necessary, and have recently published a note on the application of the complement-fixation test in the control of bovine pleuro-pneumonia in which these points are discussed (Turner and Campbell, 1937).

2. Agglutination Test.

Although the complement-fixation test is so highly sensitive and specific, its accurate performance demands a high degree of technical skill. As the agglutination test is simple and easy to perform, we have elaborated a technique and compared it with the complement-fixation test.

The presence of agglutinins in the sera of an experimentally inoculated animal was first demonstrated by Heslop (1921), and in 1922 he further demonstrated the presence of specific agglutinins of high titre in naturally affected animals showing acute symptoms, but was unable to do so in the sera of animals after clinical symptoms

had disappeared. Nevertheless, he considered his agglutination test superior to his complement-fixation test for the diagnosis and control of the disease.

Titze, Giese, and Wedemann (1923), Seelemann (1923), and Dahmen (1923) considered the agglutination test to be of value only when taken into account with clinical evidence and other serological tests. They, however, failed to obtain a positive agglutination reaction from most of their chronically affected beasts.

Nakamura, Futamura, and Watanuki (1926) compared the value of different serological methods for the diagnosis of contagious pleuro-pneumonia and obtained very disappointing results with the agglutination test.

Yamagiwa, Itabashi, and Ito (1931), in their work on the serology of the disease, frequently obtained a strong agglutination reaction with sera of normal cattle, and only when the titres progressively rose over a series of tests did they feel confidence in diagnosing the disease. Furthermore, chronic, recovering, or recovered cases gave no such rise in titre. They came to the conclusion that the agglutination test could be considered only a subsidiary to the complement-fixation test.

Technique.—The antigens used by the above workers were either prepared from cultures grown in Martin's horse-serum broth or from saline suspensions of the organism grown on the surface of serum agar slopes.

In our earlier work we were unable to obtain a satisfactory antigen, but eventually discovered that, if a formol-saline suspension of the organism were allowed to mature at 4°C. for six weeks, a very satisfactory antigen resulted. The organism is grown in B.V.F.–O.S. for seven days, then separated out in a Sharples super-centrifuge, and re-suspended in 0.2 per cent. formol-saline to a Brown's No. 2 turbidity. It is allowed to ripen or mature at 0.4°C. for six weeks before being tested in parallel with a satisfactory antigen against a number of positive and negative sera. This aging period of six weeks is always sufficient to give us a highly sensitive antigen.

The sera to be tested are set up in series by doubling the dilution in geometrical progression, and an equal volume of antigen is added to each dilution. The racks containing the test tubes are then placed in a water bath held at 55°C. After four hours they are removed and the reactions read. The tubes are held for an additional 24 hours at room temperature and then re-read.

Non-specific agglutination rarely occurs with the matured antigen. In a small percentage of sera from normal animals an incomplete agglutination may occur in the 1 in 10 dilution. Agglutination in a dilution greater than 1 in 10 is therefore taken as specific.

Agglutination Reactions with Matured Antigen following,

(*a*) *Artificial Infection with Atomized Culture.*—In animals exposed to atomized culture, agglutinins first appear between the 9th and 12th day. A maximum agglutination titre of between 1 in 320 and 1 in 1280 is reached either prior to, or immediately after, the onset of clinical symptoms; it persists there for a short interval, after which

it rapidly decreases, and even before clinical symptoms have disappeared may be completely negative. The blood sera of chronic and recovered cases always give negative reactions.

(*b*) *Subcutaneous and Tail Inoculation.*—Agglutinins usually appear between the 4th and 7th day. They rapidly increase and reach a maximum titre of 1 in 320 or 1 in 640 between the 12th and 14th day, after which the titre slowly decreases and between the 24th and the 28th day the agglutination reaction becomes negative.

3. Discussion.

Following exposure of cattle to atomized culture, complement-fixing antibodies first appear between the 6th and 10th day. One might expect that agglutinins would appear at the same time as complement-fixing antibodies, but from our work this does not appear to be so; the agglutinins appear several days later (9th–12th). Following their appearance, the agglutination and the complement-fixation reactions are approximately parallel (see Fig. 1) until clinical symptoms are shown, after which the agglutinins rapidly decrease and are often undetectable before symptoms have disappeared. The complement-fixing antibodies, however, continue to increase, and very high complement-fixation results are obtained until the beasts either succumb or are destroyed some time later.

In animals in which there are chronic, sequestrated lesions, a very strong complement-fixation reaction is always obtained, whereas the agglutination reaction is always negative.

From the above it is apparent that the agglutination test is relatively valueless in the diagnosis and control of bovine pleuro-pneumonia when compared with the complement-fixation test. It has some slight value as a confirmatory test, but even then only during the clinical phase of the disease.

4. References to Literature.

Campbell, A. D. (1938).—This *Journal*, **11**: 103.

Campbell, A. D., and Turner, A. W. (1936).—Coun. Sci. Ind. Res., (Aust.), Bull., 97.

Dahmen, H. (1923).—Cited by Ziegler (1926).—*Z. InfektKr. Haustiere*, **30**: 177.

Ebert, B. P., and Peretz, L. H. (1928).—*Z. ImmunForsch.*, **58**: 123.

Heslop, G. (1921).—*Proc. Roy. Soc. Vict.*, **33**: 160.

Heslop, G. (1922).—*J. Comp. Path.*, **35**: 1.

Nakamura, N., Futamura, H., and Watanuki, T. (1926).—*J. Jap. Soc. Vet. Sci.*, **5**: 296.

Seelemann, M. (1923).—*Arb. ReichsgesundhAmt.*, **53**: 834.

Titze, C., Giese, C., and Wedemann, W. (1923).—*Arb. ReichsgesundhAmt.*, **53**: 711.

Turner, A. W., and Campbell, A. D. (1937).—*Aust. Vet. J.*, **13**: 183.

Yamagiwa, S., Itabashi, K., and Ito, S. (1931).—*J. Jap. Soc. Vet. Sci.*, **10**: 106 and 180.

Contagious Bovine Pleuro-pneumonia : A Preliminary Note on Immunity.

By A. D. Campbell, B.V.Sc.

Summary.

1. The importance of vaccination in the control of pleuro-pneumonia in northern Australia is discussed.

2. The exposure of animals to finely atomized culture was used as a method of testing cattle for resistance produced following vaccination.

3. The results strongly suggest that, if a high and lasting immunity is to be maintained, animals should be vaccinated with a strain of the organism possessing a relatively high degree of virulence.

4. Immunity is maintained for more than twelve months when a virulent strain is used for vaccination, whereas if a comparatively avirulent strain is used immunity begins to wane after two months.

5. There is no apparent significant difference in the immunity of single- and double-vaccinated cattle when exposed at an interval of twelve months after vaccination.

6. The reactions of 51,000 head of cattle vaccinated under field conditions are discussed. A small percentage of "bad tails" and subsequent death may be expected when a vaccine prepared from a relatively virulent strain is used under field conditions, but the increased protection will usually justify its use.

I. Introduction.

Bovine pleuro-pneumonia is a highly contagious disease, and its persistence in a herd is facilitated by the apparently recovered animals with infected pulmonary sequestra. Such animals can be readily detected by the complement-fixation test (Campbell and Turner, 1936; Turner and Campbell, 1937; Campbell, 1938*b*), and if they could be quickly and totally eliminated the disease would undoubtedly disappear. However, to carry out the test, sera must be taken, cattle and their sera identified, and the animals held in isolation until the results of the test are known. The difficulties of applying such a scheme are appreciable even on a small property; on the very large properties usual in Northern Australia they would be almost insurmountable.

The most practicable method of control under such conditions is the vaccination of all cattle. While this would probably have no curative effect upon chronic cases, animals in contact with such cases would be protected, and in the course of a few years the disease might be eliminated through the lack of susceptible beasts and the gradual disappearance of chronic cases. Unfortunately, up to the present very little is known of the degree and duration of resistance produced as a result of vaccination. It has always seemed to us that the testing of immunity by subcutaneous inoculation of cultures is of doubtful value and is too severe. On the other hand, it is very difficult to arrange, and control, experiments to test immunity by exposure to natural infection, which is at best a matter of chance. Our technique (Campbell, 1938*a*) for reproducing the disease experimentally in a manner simulating natural infection has allowed us to study induced resistance under controlled conditions.

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Vaccination was first used in the control of the disease by Willems in Belgium in the middle of last century. He introduced the method of tail inoculation extensively used in Australia to-day. To avoid the occasional bad sequelae of this method, some workers have introduced other methods. Bennett (1932), working in the Sudan, uses the subcutaneous inoculation of attenuated cultures with success. Curasson (1930) and Verboff (1934) have claimed good results from the use of formalized pleuritic exudate given subcutaneously in large quantities. We have been unable to confirm Curasson's claims, nor could we even demonstrate any complement-fixing antibodies in the blood sera of treated animals.

In all our vaccination work, we inoculated 0.2 ml. of four-day cultures in B.V.F.-O.S.* by means of a hypodermic needle and syringe into the tip of the tail. Other than cutting the long hairs from the tip of the tail, no aseptic precautions were observed. Clinical observations were made twice a week; at the same time blood sera were collected for serological tests.

If the virulence of the particular strain used in the preparation of the vaccine is not excessive, the first indication of a reaction is obtained between the second and third day, when a slight swelling appears at the tip of the tail. It becomes more apparent by the seventh day, when a well-marked, inflammatory, oedematous reaction will be found extending upwards from 1½ to 3 inches. Usually by this time there is a "bottling" or sharp limitation of the infection to that area. Occasionally, however, the reaction may extend up to 12 inches, but only in two animals out of 300 tail-inoculated by us at the Laboratory has the reaction extended into the gluteal muscles, and in both these cases the termination was not fatal.

We have made it a practice not to interfere with a "bad tail" until dry necrosis commences, and then the necrotic tissue is removed distal to the apparently normal.

We have never experienced the rapid extension of the inflammatory reaction that often is a serious sequel to the removal of the distal portion of the tail of excessively reacting cattle under field conditions. Possibly these amputations are made too soon, and the resulting trauma in the apparently healthy tissue favours the proliferation and extension of the organism to the gluteal and perineal regions.

In an endeavour to produce as high a degree of immunity as possible, we have carried out experiments on the possibility of reinforcing the immunity produced by tail vaccination with subcutaneous injection of a larger amount of culture behind the shoulder.

2. Serological Response following Tail Inoculation.

(a) Complement-fixing Antibodies.

Complement-fixing antibodies usually first become detectable between the 3rd and 7th day after tail inoculation. They rapidly increase, and reach a maximum of iv/640 or greater between the 10th and 14th day, after which they slowly decrease until between the 7th and 14th week they can be no longer detected. Occasionally, if the tail reaction has been

* Campbell, A. D., and Turner, A. W. (1936).—Coun. Sci. Ind. Res. (Aust.), Bull., 97, p. 74.

severe, they persist for a longer period, and following gluteal involvement may persist at a reaction of iv/20 or greater for even longer than 12 months.

The complement-fixation reaction appears to be closely related to the severity of the infection, for usually the highest titres are obtained from the sera of cattle with extensive reactions in the tail.

(*b*) *Agglutination Antibodies.*

The appearance of agglutinins is usually concurrent with the appearance of complement-fixing antibodies. However, agglutinins can only be demonstrated in serum dilutions of 1 in 160 to 1 in 320, and after reaching a maximum between the 10th and 14th day rapidly disappear and cannot be detected after the 28th day.

3. Rapidity of Development of Resistance.

A problem of practical importance is how soon, after tail vaccination, cattle develop a resistance against contagious bovine pleuro-pneumonia. Two experiments that we have carried out throw some light on this.

In the first experiment, 24 head of cattle were tail-inoculated, divided into 4 groups of 6 head, and at various intervals after vaccination exposed to atomized culture. Group A was exposed after 4 days, Group B after 11 days, Group C after 18 days, and Group D after 26 days. Six control animals were included with the 1st and 4th groups, but owing to lack of accommodation none were included with the second and third groups.

In the second experiment, 30 head of cattle were divided into 5 groups (a, b, c, d, e) of 6 head, and were tail-inoculated at various intervals so arranged that the final testing of immunity was carried out at the one operation, each group having three control animals. The intervals after vaccination were 3, 7, 14, 28, and 56 days respectively.

For convenience, the results of the two experiments, although not strictly comparable, are grouped together in Table 1.

Table 1.—Rapidity of Development of Immunity.

Group.	Tail-Inoculated Animals.				Controls.		
	Interval in Days After Tail Inoculation.	Number of Animals in Group.	Developed Pleuro-Pneumonia.	Resistant.	Number of Animals in Group.	Developed Pleuro-Pneumonia.	Resistant.
a	3	6	1	5	3	3	0
A	4	6	1	5	6	6	0
b	7	6	2	4	3	3	0
B	11	6	0	6	..*	..*	..
c	14	6	1	5	3	3	0
C	18	6	0	6	..*	..*	..
D	26	6	0	6	6	5	1
d	28	6	1	5	3	2	1
e	56	6	0	6	3	3	0

* No controls were available in these instances.

It is evident from the above that the exposure to atomized culture produced a very high percentage of cases of pleuro-pneumonia in the unvaccinated control animals (25 out of 27). On the other hand a high degree of resistance was present in the vaccinated cattle. The proportion of resistant animals amongst the vaccinated fluctuates a little and is probably due to the relatively small groups. It is surprising that even as early as the 3rd and 4th day after vaccination a high degree of resistance was produced (10 out of 12 as against none out of 9 controls). From this experiment one is unable to state when maximum immunity is produced, but it appears to be very early, possibly within two or three weeks or even earlier.

4. Duration of Immunity.

A problem of great economic importance is how long cattle remain immune after vaccination.

Two sets of experiments were carried out simultaneously—

(*a*) Tail vaccination alone with 0.2 ml. of culture.

(*b*) Tail vaccination, followed after a period of eight weeks by a reinforcing subcutaneous inoculation of 2.0 ml. of culture.

The tail vaccinations in group (*a*) were carried out when those in group (*b*) were given the reinforcing vaccination.

Twenty-six animals were included in each group, each of which was subdivided into two sub-groups. Two sub-groups containing 12 animals each were exposed to atomized culture six months after tail vaccination or the reinforcing vaccination respectively; the other sub-groups were tested six months later. The results obtained from the two sub-groups exposed after an interval of six months were that 11 out of 12 animals of each group were totally resistant, whereas 6 control animals all developed hyperacute pleuro-pneumonia. The non-resistant animal in the single-vaccinated group died from the disease after showing hyperacute symptoms. That in the double-vaccinated group showed no clinical evidence of having become affected, but the disease was diagnosed by the complement-fixation test; at outopsy, a small sequestrated lesion was found in one of the lobes of the lungs. The susceptibility of this double-vaccinated animal possibly may have been influenced by parturition, which occurred 24 hours prior to artificial exposure.

The results obtained when the remaining two sub-groups were exposed twelve months after tail-vaccination and reinforcing vaccination respectively, were that 12 out of 12 single-vaccinated and 14 out of 14 double-vaccinated animals were totally resistant, whereas 6 controls contracted pleuro-pneumonia.

It is apparent from these two experiments that a high degree of resistance is produced in animals following tail inoculation; further, this resistance lasts for a period longer than twelve months. From the results, there is no apparent significance between the resistance conferred by the double inoculation over that conferred by a single inoculation.

It is possible that a significant difference may be obtained if the experiment is carried out over a period of several years.

5. Serological Behaviour of Single- and Double-vaccinated Animals following Exposure to Atomized Culture.

An interesting difference is noted in the serological response of single- and double-vaccinated animals following exposure to artificial infection.

Double-vaccinated animals (Fig. 1) usually show a very rapid rise of complement-fixing antibodies, which persist in high titre for several weeks, after which they slowly disappear. Single-vaccinated animals (Fig. 2), on the contrary, give but a slight rise in antibody titre, which rapidly disappears.

6. Influence of the Pathogenicity of the Organism used in the Preparation of Vaccine.

(*a*) *Tail Reaction.*

Some strains are less pathogenic when injected by this route; they cause a much less severe tail reaction than when others are used. The reactions are confined to the very tip of the tail and never extend up further than 1 inch, whereas with the more virulent types more severe reactions are produced.

(*b*) *Complement-fixation Response.*

The complement-fixation response following vaccination of cattle with a strain of the organism that produces only very mild tail reactions is not nearly so great, nor does it persist for such a long period, as when a more virulent strain is used.

(*c*) *Degree and Duration of Resistance.*

Interesting information was obtained at the completion of two experiments in which cattle were vaccinated with a strain of the organism which gave only a slight degree of swelling at the tip of the tail, and correspondingly a moderate type of serological response.

In the first experiment, 18 head of cattle were vaccinated and divided into two groups which were exposed along with eight controls *per* group after an interval of 6 and 10 months, respectively. The results of this experiment were as follows:—

	Vaccinated Animals.			Controls.		
	Number of Animals in Group.	Resistant.	Susceptible.	Number of Animals in Group.	Resistant.	Susceptible.
Group A exposed six months after vaccination	9	8	1	8	0	8
Group B exposed ten months after vaccination	9	6	3	8	1	7

From these results it is seen that after an interval of ten months an apparent lowering of the resistance of the vaccinated cattle had occurred.

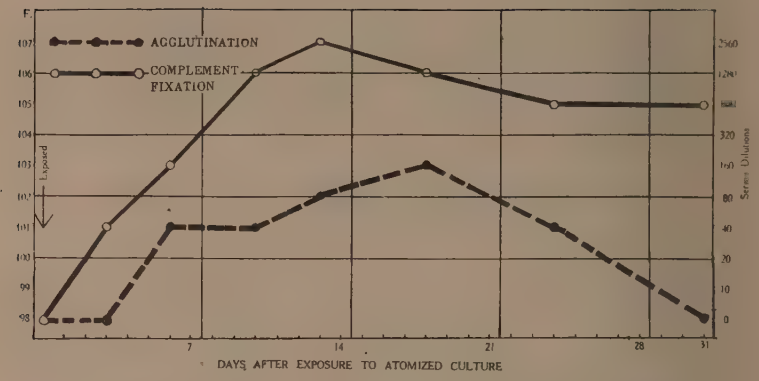

FIG. 1.—Serological chart of a double-vaccinated animal after exposure to atomized culture. This animal had been vaccinated at the tip of the tail with 0·2 ml. culture on 10.11.36 and then subcutaneously behind the shoulder with 2·0 ml. on 4.1.37. It was exposed to atomized culture on 14.1.38, and it remained resistant to the disease.

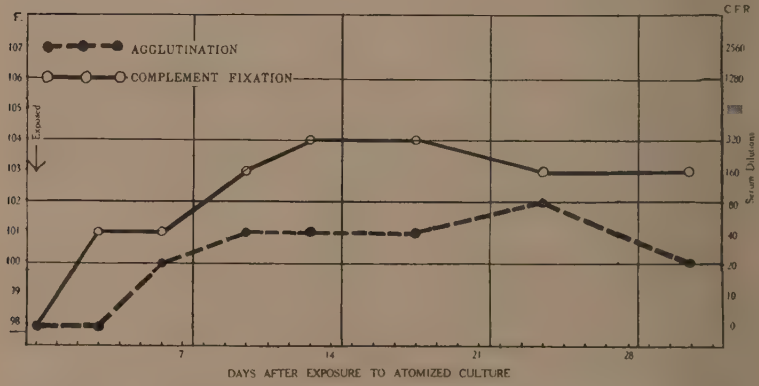

FIG. 2.—Serological chart of a single-vaccinated animal after exposure to atomized culture. This animal had been vaccinated at the tip of the tail with 0·2 ml. culture on 4.1.37. It was exposed to atomized culture on 14.1.38 and it remained resistant to the disease.

In another experiment, six animals were vaccinated with vaccine prepared from a culture possessing a high degree of pathogenicity, and a further six were vaccinated with a strain possessing a much lower degree of pathogenicity, as judged from subcutaneous inoculation of susceptible animals. Clinical and serological data collected following vaccination show that the animals vaccinated with the virulent culture exhibited a more severe type of tail reaction and much higher complement-fixation reactions than those vaccinated with the less virulent strain.

These twelve head of cattle with six control animals were exposed after an interval of two months. The results are as follows:—

	Number of Animals in Group.	Resistant.	Susceptible.
Animals vaccinated with virulent strain ..	6	6	..
Animals vaccinated with attenuated strain ..	6	4	2
Controls	6	1	5

This experiment suggests more conclusively the importance of using a vaccine prepared from cultures as virulent as is consistent with safety.

7. Use of the Culture Vaccine in the Field.

Vaccine for use under field conditions is prepared from a strain of the organism that still possesses a relatively high degree of virulence.

The organism is grown in B.V.F.-O.S. contained in bottles of convenient sizes. The bottles are incubated for a period of 72 hours, after which they are removed and examined for chance contamination, stoppered, and then replaced in the incubator for another 24 hours. They are then removed, examined, and given the vaccine batch number. Several bottles are set aside for an estimation of the bacterial count, and if growth is obtained with an inoculum of at least 10^{-8} ml. the batch is distributed for field use. Although tests have shown that the titre remains above this level often for periods as long as five months, as a routine it is stipulated that the vaccine must be used within two months of issue. Approximately 600,000 doses have been issued for use in the field during the last three years.

In the preparation of the vaccine for field distribution, so far only two strains of the organism have been used (Strains C288 and V5). Strain C288 was isolated from a natural case of contagious pleuro-pneumonia in February, 1934. This strain was used exclusively for the preparation of vaccine until the end of 1936, when it was found in our experiments at the Laboratory that animals vaccinated by it did not possess a high degree of resistance. It was therefore replaced by a comparatively recently isolated strain, V5.

This strain produced good, but not alarming, reactions when inoculated into the tip of the tail of cattle, and subsequent exposure experiments showed that it conferred a very high and lasting resistance.

Vaccine prepared from this strain was first despatched to Queensland in January, 1937. Distribution was continued until the end of June, when, following reports of bad tails and subsequent deaths of a number of animals, it was discontinued and replaced by C288. However, additional work confirmed the superiority of V5 as an immunizing agent. C288 was replaced by V5 in November for vaccine preparation.

From the experimental results, it is apparent that a vaccine prepared from a strain of the organism possessing a high degree of virulence must be used if a high and lasting immunity is to be maintained in an animal. Therefore, when such a vaccine is used for field inoculation, it is only to be expected that a small percentage of bad tails and deaths will occur.

Returns collected from Queensland concerning 51,000 head of cattle which were vaccinated with V5 vaccine show that 1.03 per cent. of cattle developed bad tails, and the mortality rate was 0.18 per cent.; this indicates that bad reactions and deaths are negligible when compared with the protection afforded.

8. References to Literature.

Bennett, S. C. J. (1932).—*J. Comp. Path.*, **45**: 257.

Campbell, A. D. (1938*a*).—This *Journal*, **11**: 103.

Campbell, A. D. (1938*b*).—This *Journal*, **11**: 112.

Campbell, A. D., and Turner, A. W. (1936).—Coun. Sci. Ind. Res., (Aust.), Bull., 97.

Curasson, G. (1930).—*Bull. Acad. Vét.*, **3**: 322.

Turner, A. W., and Campbell, A. D. (1937).—*Aust. Vet. J.*, **13**: 183.

Verboff, A. M. (1934).—*Sovetsk. Vet.*, **11**: 24.

The Yield and Composition of a Mitchell Grass Pasture for a Period of Twelve Months.

By J. Griffiths Davies, B.Sc., Ph.D., A. E. Scott, M.Sc.,† and J. F. Kennedy, B.Agr.Sc.‡*

The work discussed in the article that follows forms a part of a co-operative programme of investigations in which the Waite Agricultural Research Institute of the University of Adelaide, the Carnegie Corporation of New York, and the Council for Scientific and Industrial Research co-operated. The Empire Marketing Board also contributed to the scheme in the early years (see this *Journal* 5: 141, 1932). When the Board was disbanded and its contribution ceased, the Carnegie Corporation contributed a sum of £1,750 for one year and a sum of £900 for a second year towards the cost of investigations, conditional on an undertaking being given that the work would be continued after the close of the second year. The second year expired in 1936, and the programme is now being continued as a co-operative investigation of the Waite Institute and the Council.—Ed.

1. Introduction.

The droughts experienced in the pastoral belts of western Queensland cause severe loss of stock due to scarcity of fodder. In good seasons, however, the production is greater than required for the normal stocking that can be carried on the holdings. This really means that the rate of stocking is determined largely on the carrying capacity of the holdings in the drought periods. Unfortunately, it is not yet practicable to reserve fodder grown in the good seasons for use during times of severe drought, although a measure of drought reserve is possible by reserving channel country and the timbered ridges. On the open downs formations, nothing is achieved by reserving the standing herbage. The light rains in the dry season of the year ruin the dried-off herbage, a process commonly referred to as "blackening off" rendering it quite useless.

The extent of the deterioration of standing pastures has been investigated in the case of a natural pasture in the winter rainfall belt of South Australia by Davies, Scott, and Fraser (1). They showed that, during the dry period of the summer months, a serious deterioration in both quality and quantity of herbage occurred, resulting in marked loss of weight of the sheep grazing such pastures. In Queensland, where prolonged droughts sometimes extending for two or more seasons are experienced, it is to be expected that this deterioration will be even greater on account of the longer duration of drought and of the summer incidence of the rainfall.

The present experiment was designed to obtain some knowledge of the total and the seasonal yield and composition of a Mitchell grass pasture on a western Queensland sheep station. The experiment was conducted in collaboration with the Australian Estates Company on the station "Elderslie," near Winton, Queensland. The station comprises some 300,000 acres and carries normally about 43,000 sheep,

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140 horses, and 30 cattle. The average annual rainfall (Table 1) at the homestead is 13.23 inches for a total of 36 years (not consecutive) from 1888. The climate is typically sub-tropical, with a summer rainfall incidence, although in some seasons useful winter rains occur.

TABLE 1.—RAINFALL IN POINTS (1-100TH INCH) AT "ELDERSLIE" STATION HOMESTEAD, 1888-1936 (NOT CONSECUTIVE).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1888	95	473	15	0	157	0	0	0	0	0	19	31	790
1889	171	62	122	136	105	177	13	36	10	0	113	161	1,106
1897	169	93	5	0	0	95	0	0	40	122	0	57	581
1898	180	1,278	3	0	0	37	0	12	63	29	23	34	1,659
1899	134	316	127	68	0	0	151	23	0	3	28	29	879
1900	132	33	2	0	17	16	204	0	35	0	52	0	491
1901	8	85	658	107	112	10	0	30	23	7	22	0	1,062
1902	135	46	58	0	0	0	0	9	18	0	133	122	521
1903	322	0	169	58	70	0	8	0	90	168	36	751	1,672
1910	264	287	127	19	0	81	132	0	96	0	390	44	1,440
1911	466	132	35	75	20	0	75	0	49	0	682	289	1,823
1912	192	180	118	0	0	542	97	0	0	0	99	182	1,410
1913	77	815	7	364	10	22	0	0	11	40	11	67	1,424
1914	509	427	8	10	0	89	0	0	0	153	97	224	1,517
1915	148	18	0	0	234	0	2	15	152	0	0	559	1,128
1916	818	186	0	0	0	32	293	32	16	229	213	789	2,608
1917	375	703	594	0	0	0	8	102	116	54	471	122	2,545
1918	1,254	172	223	30	0	0	7	12	4	0	8	47	1,757
1919	154	434	14	50	57	0	0	0	0	0	0	30	739
1920	617	79	219	209	292	155	400	22	42	106	394	205	2,740
1921	45	133	470	49	27	157	0	0	5	487	0	529	1,902
1922	839	355	0	0	0	15	0	0	0	0	0	470	1,679
1923	38	179	11	0	30	299	0	0	0	19	12	39	627
1924	296	886	202	285	0	0	0	60	22	169	327	721	2,968
1925	62	289	334	0	0	0	0	0	0	13	322	0	1,020
1926	20	20	5	0	45	0	0	0	174	0	0	32	296
1927	83	69	115	0	0	35	0	0	30	44	0	384	760
1928	0	14	29	48	0	39	20	0	0	0	47	290	487
1929	419	0	392	205	0	3	0	0	0	0	57	136	1,212
1930	813	480	0	0	218	32	0	0	0	402	0	153	2,098
1931	21	0	293	32	80	16	0	0	57	0	119	66	684
1932	0	47	25	31	337	17	0	0	0	9	38	0	504
1933	35	392	23	0	0	66	223	0	0	8	363	24	1,134
1934	412	433	0	75	0	137	121	0	0	67	40	0	1,284
1935	127	0	0	0	0	569	4	0	67	46	..	..	..
1936	..	408	585	0	..	0	..	..	..	..	89	62	..

The paddock records for years 1935 and 1936 are as follows:—

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1935	127	0	0	0	0	569	4	0	67	46	58	33	904
1936	368	408	685	0	273	0	26	15	0	0	89	62	1,926

The flora on the station may be divided into four well defined botanical associations—

1. Open Downs—dominantly Mitchell grass plains on two soil types, a brown and a grey soil. (Pl. 2, Fig. 2; Pl. 3, Figs. 1 and 2; Pl. 4, Fig. 1.)

2. Channels and Claypans—carrying chiefly coarse grasses and sedges with herbages and shrubs. (Pl. 1, Figs. 1 and 2.)
3. Ironstone ridges—carrying gidyea (*Acacia Cambogei*) and "light" grasses—*Panicum* spp., *Sporobolus* spp., *Pappophorum nigricans*, and *Aristida ramosa*. (Pl. 2, Fig. 1.)
4. Rough, hilly country—carrying chiefly spinifex (*Triodia lanata*).

The main association—and the most important one—is the Open Downs. The paddock selected for the experiment was mainly of this association (Pl. 4, Fig. 1), the soil being of a red-brown type, a loose and ashy surface horizon of 4–6 inches overlying a heavy clay. Topographically, the formation is flat to slightly undulating, the open plain being entirely treeless and devoid of shade.

The grass flora, in general, responds to the summer rainfall, whilst the small annual species ("herbage") make their main growth after winter rains. The absence of clovers and medics is a feature of the flora, the only representative of the Leguminosae in the herbaceous flora of the experimental area being *Desmodium campylocaulon*, although *Crotalaria incana* is occasionally present in the Open Downs.

2. Experimental Procedure.

Within the selected paddock, a small area, as typical as possible of the whole, was chosen. On this area, 18 plots, each of 1 square chain, were laid out as shown in the plan (Fig. 1). Nine of the plots were protected from grazing whilst the remaining nine were open to grazing by the flock of sheep carried in the paddock.

—	Ungrazed.			Grazed.		
300 links	B_1	A_1	C_1	E_1	D_1	F_1
	C_2	B_2	A_2	F_2	E_2	D_2
	A_3	C_3	B_3	D_3	F_3	E_3

FIG. 1.—Layout of experiment—"Elderslie" Station.

The rate of stocking from September, 1935, to April, 1936, was a sheep to 4½ acres; from April onwards, the rate of stocking was increased by lambing and is computed to approximate one sheep to 3 acres. Mortalities occurred, and a lamb has been estimated as one-third of a mature sheep from April onward.

At monthly intervals and commencing in September, 1935, 5 x 5 link quadrats were harvested on each of the 18 plots, and the herbage air-dried and forwarded to the Waite Institute for weighing, and botanical and chemical analyses. Fourteen cuts were made, the last cut being on 23rd September, 1936, and giving a complete year. The sampling area on the plots was changed each month, thus obviating any effects of previous cutting.

3. Botanical Composition and Yield.

The samples as received at the Waite Institute were sub-sampled when necessary to reduce the bulk. They were then hand separated into four classes—

1. Perennial grasses—including the four species of *Astrebla*, but mainly *A. squarrosa* and *A. pectinata*.
2. Annual grasses—chiefly *Panicum decompositum*‡ with small amounts of *Eriochloa punctata, Sporobolus Lindleyi*, and *Iseilema membranacea* (Flinders grass).
3. Miscellaneous herbage.—The constituent species of this group differed in the winter and summer. From January, 1936, onward the main species was *Desmodium campylocaulon*, with small amounts of a twining climber—probably *Ipomoea lonchophylla*—and some very small amounts of unidentified species.

   In the October-December cuts, the chief species were *Calotis hispidula* (Bindyei), *Plantago varia, Helipterum pygmaeum, Daucus carotus*, and *Malva parviflora*. Of these, traces of *Calotis, Helipterum*, and *Malva* were occasionally noted in the summer herbage.
4. Inert material—including dead plant remains, soil, and debris of all kinds.

After separation, the main sample, as well as the separates of the sub-sample, were oven-dried for two days at 102°C., weighed, and the constituents of the total sample calculated. The yield data has been subjected to statistical analysis, the nine plots of the grazed and ungrazed section being treated as Latin squares of three treatments.

A. *Yield.*

The rainfall immediately before and during the experimental period is given in Table 2.

TABLE 2.—THE RAINFALL IN POINTS FROM 1ST JUNE, 1935, TO 23RD SEPTEMBER, 1936, AT THE EXPERIMENTAL AREA.

Period.	Rainfall in Points.*
June, 1935	569
July, 1935	4
August 1935–7th September	0
8th September–21st October	75
21.10.35–19.11.35	96
20.11.35–17.12.35	33
18.12.35–21.1.36	368
22.1.36–18.2.36	213
19.2.36–13.3.36	476
14.3.36–8.4.36	404
9.4.36–6.5.36	40
7.5.36–2.6.36	233
3.6.36–30.6.36	0
1.7.36–30.7.36	26
31.7.36–25.8.36	15
26.8.36–23.9.36	0

* 1 point = 1-100th of an inch.

‡ This identification is open to question. Mr. C. T. White, Government Botanist, Queensland, regards this as an unnamed species of *Panicum*, distinct from *P. decompositum*.

A heavy rain in June, 1935, resulted in appreciable growth, but no follow-on rains of any importance were received in July and August, whilst the rains from September to December were too light to be of value for growth. The pasture was sampled for the first time on 23rd September, 1935, the herbage then being practically all dry. This cut was unfortunately so badly pulverized in transit that botanical separation was impossible, and reliable yield figures could not be ascertained. Summer rains commenced on 6th January, 1936, and good falls were received during January, February, and March. This led to an excellent growth of summer pasture.

The monthly yield data are given in Table 3 in cwt. per acre of oven-dried material, 13 cuts being included in this table; they are also shown graphically in Fig. 2. The total yield includes all pasture that had obviously grown during the season. (From January onward the small amounts of miscellaneous species resulting from the June, 1935, rain were classed as inert.) The yields given are the progressive monthly totals and are not, of course, the actual production during the month preceding the cut.

The most striking feature of the data is the rapid increase in yield during February and March. Thus the total yield on the ungrazed section on 21st January was .42 cwt. per acre; four weeks later—18th February—it was 1.71 cwt. per acre; three weeks later—10th March—it was 10.99 cwt. per acre; whilst by 8th April the peak yield of 17.88 cwt. was recorded.

From April onward, the yield tends to decline slowly as the various constituents of the pasture attain maturity, shed their seed and leaves, and, in the case of the perennial species, transfer food reserves underground. The yield remains at a relatively high value to the last

TABLE 3.—YIELD IN CWT. PER ACRE FOR 13 MONTHLY CUTS AT "ELDERSLIE" STATION, OCTOBER, 1935, TO SEPTEMBER, 1936.

Date of Cut.	Total Yield.		Perennial Grasses.		Annual Grasses.		Miscellaneous Herbage.	
	Ungrazed.	Grazed.	Ungrazed.	Grazed.	Ungrazed.	Grazed.	Ungrazed.	Grazed.
22.10.35	1·40	1·20	0·51	0·37	0·04	0·03	0·86	0·81
19.11.35	1·14	0·65	0·62	0·26	0·01	0·005	0·50	0·38
17.12.35	0·87	0·51	0·46	0·12	0·009	0·010	0·39	0·36
21.1.36	0·42	0·12	0·39	0·11	..	..	0·02	0·02
18.2.36	1·71	2·06	1·05	1·64	0·10	0·09	0·56	0·34
10.3.36	10·99	9·40	4·23	5·63	3·78	1·78	2·96	2·00
8.4.36	17·88	18·10	10·58	13·60	4·98	3·43	2·33	1·07
6.5.36	17·56	15·85	10·81	10·56	5·41	4·68	1·33	0·61
2.6.36	14·49	15·82	9·43	11·82	2·87	3·05	2·19	0·94
30.6.36	15·68	17·96	10·22	16·47	3·41	0·88	2·05	0·60
30.7.36	15·63	15·48	9·25	13·06	5·58	2·00	0·81	0·42
25.8.36	14·77	12·88	10·30	10·17	3·75	2·42	0·72	0·30
23.9.36	13·16	15·86	10·82	12·38	2·06	3·28	0·27	0·21
	S.E. 1·361 cwt. per acre		S.E. 1·307 cwt. per acre					

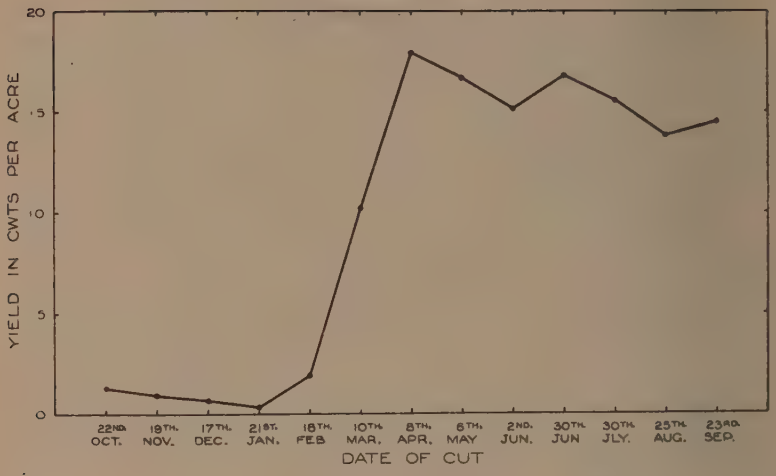

Fig. 2.—Mean oven-dry yield of pasture at "Elderslie."

of the cuts in September, 1936, when compared with the yield in October, 1935—after poor summer rains, but one good winter rain. The low yields in October, 1935, became progressively less till January, 1936, when less than ½ cwt. per acre of edible herbage was present.

(It will be noted that the standard error of the yields—both of total yield and of perennial grasses—is high, and that for differences in total yield to be significant they must exceed 1.36 x 3 = 4.08 cwt. per acre.)

Comparison of the yields from the grazed and ungrazed sections of the experiment show that on the whole the effect of grazing was not measurable. There is, however, some suggestion that a difference is present from October, 1935, to January, 1936, the yields being greater in the protected plots. This agrees with our observations; after January no traces of grazing were seen in the samples.

The rate of stocking was very light in relation to the summer growth of the pasture, being less than one-quarter of a sheep per acre, until after the peak production, and thereafter increased to slightly under one-third of a sheep per acre. Thus, on the assumption that one sheep will need approximately 10 cwt. of dry matter per annum, the consumption per acre in twelve months will be 3.3 cwt. at one-third of a sheep per acre. In monthly cuts, therefore, it becomes necessary to detect such a minute difference as 3.3/12 = 0.275 cwt. before the effect of grazing is measurable The technique employed is only capable of measuring differences greater than 1.36 cwt. per acre. It is, therefore, necessary to regard the two Latin squares as showing no difference due to grazing, and it is permissible to average the yield from the ungrazed and grazed sections to give a more reliable estimate of the monthly yields. In Table 4 these mean yields are shown.

TABLE 4.—MEAN YIELD OF GRAZED AND UNGRAZED FOR 13 MONTHLY CUTS.

Cut.	Yield in cwt per acre.
22nd October, 1935	1.30
19th November, 1935	0.90
17th December, 1935	0.69
21st January, 1936	0.27
18th February, 1936	1.89
10th March, 1936	10.20
8th April, 1936	17.99
6th May, 1936	16.71
2nd June, 1936	15.16
30th June, 1936	16.82
30th July, 1936	15.56
25th August, 1936	13.83
23rd September, 1936	14.51

S.E. 0.963 cwt. per acre.

Significant difference > 2.89 cwt. per acre.

These mean yields show more clearly the trend downward in yield from the April cut onward, and that the August and September yields in 1936 are significantly lower than the April, 1936, yield.

B. *Botanical Composition.*

The botanical composition shows two quite clearly defined stages:—

1. The pasture after the winter rains in June.
2. The pasture after the summer rains.

This is shown in Table 5 where the percentage contribution of the three species groups to the total yield is given.

TABLE 5.—THE PERCENTAGE CONTRIBUTION OF THE THREE SPECIES GROUPS TO THE TOTAL YIELD IN EACH OF THE THIRTEEN MONTHLY CUTS.

Date of Cut.	Total Yield.		Botanical Constituents in per cent.		
	In cwt. per Acre.	In per Cent.	Perennial Grasses.	Annual Grasses.	Miscellaneous Herbage.
22.10.35	1·30	100·00	33·59	2·67	63·74
19.11.35	0·90	100·00	49·58	0·84	49·58
17.12.35	0·69	100·00	42·99	1·41	55·60
21.1.36	0·27	100·00	92·59	Nil	7·41
18.2.36	1·89	100·00	71·16	5·03	23·81
10.3.36	10·20	100·00	48·38	27·28	24·34
8.4.36	17·99	100·00	67·20	23·36	9·44
6.5.36	16·71	100·00	63·98	30·21	5·81
2.6.36	15·16	100·00	70·13	19·54	10·33
30.6.36	16·82	100·00	79·36	12·76	7·88
30.7.36	15·56	100·00	71·69	24·36	3·95
25.8.36	13·83	100·00	74·00	22·31	3·69
23.9.36	14·51	100·00	79·95	18·40	1·65

In the first stage—the winter rain pasture—the dominant group is the miscellaneous herbage, with the Mitchell grasses as sub-dominant, whilst the annual grasses show little response to the winter rains.

The summer rains commenced on 6th January, when 120 points fell, followed by a good soaking rain from the 7th January to the 13th January, the first group to respond being the Mitchell grasses, the percentage contribution of which rose to a peak of over 92 per cent. of the total herbage, whilst the annual grass contribution was nil. The next group of species to respond to the rain was the miscellaneous, which by 18th February was contributing 24 per cent. of the total, whilst the annual grasses were still only small contributors with 5 per cent.

At the cut on 10th March, both the annual grasses and the miscellaneous species were appreciable contributors with 27 per cent. and 24 per cent. respectively, whilst the Mitchell grasses had declined very rapidly from the high January figure of 92 per cent. to 48 per cent. in March. From March onward, the Mitchell grasses gradually increased their percentage contribution, until the end of June when the pasture was again 80 per cent. Mitchell grasses. The annual grasses apparently slowly declined from May onward, but the figures fluctuate rather markedly. The miscellaneous species with, of course, *Desmodium campylocaulon* as the chief species, suddenly drop in their importance after early March, and seem to decline fairly steadily to the low figure of 1½ per cent. in the final cut.

It is apparent that the perennial Mitchell grasses respond first to rain; the annuals having to start growth from seed take longer to make appreciable contributions to the yield. These species, however, grow more rapidly and attain maturity in a very short period, this being specially noticeable in the miscellaneous herbage which declines in yield after 10th March, whilst the annual grasses tend to decline in yield from May onward. The decline in yield of the Mitchell grasses is slower, resulting in a gradually increased percentage of these species in the pasture. This is due to the fact that the Mitchell grasses mature more slowly and are more robust, allied with the fact that there is a much smaller proportion of seed to total yield as compared with the annual species.

4. Chemical Composition.

After botanical analysis, the nine samples from each of the grazed and ungrazed areas were bulked separately for chemical analysis. The error introduced by bulking is small, as shown by Table 6, in which are recorded the values obtained by bulking nine replicates from the grazed area, in groups of three.

The values for the bulked samples should approximate closely to the above means even if the yields vary appreciably, since the effect of yield variation on chemical composition is small unless the constituent species show wide variations in composition.

Some of the samples were found to be contaminated by fine soil particles. An estimation of this was made and the necessary corrections applied to the analytical results.

TABLE 6.—SHOWING VARIABILITY OF GROUPS OF THREE REPLICATES.

Date.	Sample.	Protein.	Phosphorus (P).
21.1.36	A	17·3	·206
	B	17·4	·206
	C	17·1	·207
	Mean	17·3	·206
18.2.36	A	14·9	·178
	B	14·8	·180
	C	14·9	·176
	Mean	14·9	·178
10.3.36	A	9·9	·152
	B	9·9	·155
	C	9·8	·151
	Mean	9·9	·153
2.6.36	A	4·6	·076
	B	4·3	·069
	C	4·3	·069
	Mean	4·4	·071
23.9.36	A	3·1	·050
	B	3·3	·047
	C	3·3	·049
	Mean	3·2	·049

Results.

The chemical work included determinations of the contents of protein, fibre, phosphorus, and calcium throughout the season. The variations in composition are illustrated in Figs. 3 and 4. Complete details are to be found in Table 7.

TABLE 7.—COMPOSITION OF NATURAL PASTURE—"ELDERSLIE," 1935-6.

Date.	Crude Protein.		Phosphorus (P).		Calcium (Ca).		Crude Fibre.	
	Grazed.	Ungrazed.	Grazed.	Ungrazed.	Grazed.	Ungrazed.	Grazed.	Ungrazed.
23.9.35	10·0	10·5	·142	·148	·28	·29	32·9	32·1
22.10.35	8·2	8·3	·131	·130	·30	·31	34·1	34·6
19.11.35	6·9	7·1	·081	·078	·30	·32	37·3	36·9
17.12.35	5·5	5·5	·082	·091	·34	·30	39·4	38·3
21.1.36	17·3	16·6	·206	·196	·31	·28	25·0	26·1
18.2.36	14·9	13·8	·178	·168	·30	·28	27·1	28·9
10.3.36	9·9	9·6	·153	·140	·39	·31	34·9	34·9
8.4.36	9·1	8·5	·126	·123	·30	·33	34·2	35·4
6.5.36	5·0	5·9	·100	·095	·29	·31	34·7	34·0
2.6.36	4·4	5·4	·071	·084	·28	·30	34·9	33·8
30.6.36	4·0	5·1	·058	·070	·32	·34	33·9	33·6
30.7.36	3·6	4·9	·050	·068	·29	·31	34·8	32·9
25.8.36	3·2	4·7	·048	·070	·33	·32	34·0	34·0
23.9.36	3·2	4·6	·049	·066	·32	·31	35·0	33·2

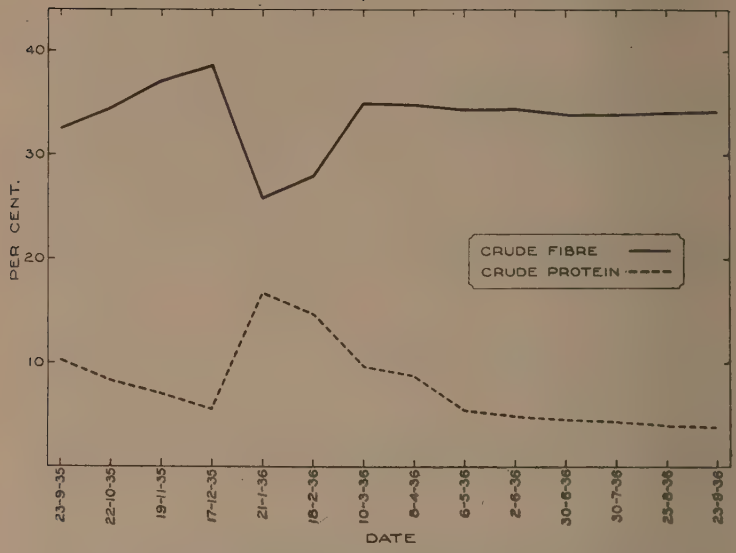

Fig. 3.—Showing variations in the content of crude protein and crude fibre in a Mitchell Grass pasture, "Elderslie," 1935–1936.

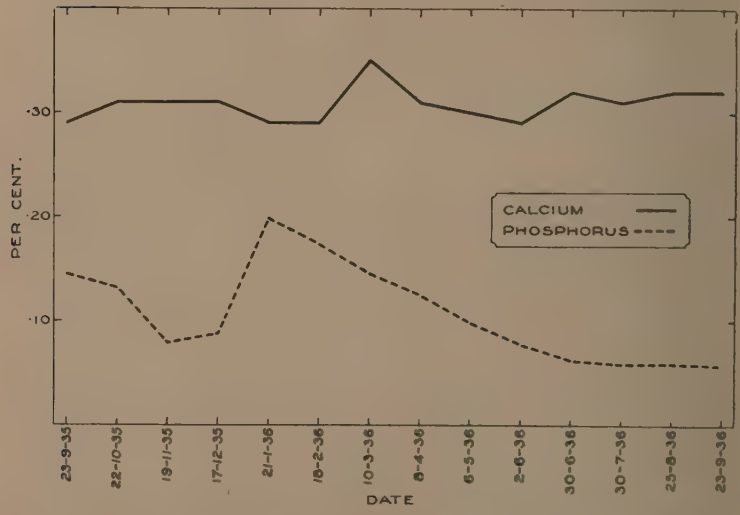

Fig. 4.—Showing variations in the content of calcium and phosphorus in a Mitchell Grass pasture, "Elderslie," 1935–1936.

Phosphorus, protein, and fibre all show definite seasonal trends, two periods of relatively high quality and productivity being apparent. The pasture made good growth as a result of the rain which fell in June, 1935, and although a period of very dry weather followed the mature herbage cut on the 23rd September, 1935, contained 10 per cent. of protein. Thereafter the quality deteriorated considerably, this

constituent being reduced to 5.5 per cent. by 17th December, 1936. The January rains, however, enabled fresh growth to be made by the 21st January, at which cut protein amounted to 17 per cent.—the highest value recorded during the experiment. During the three weeks from 18th February to 10th March, it fell from 15 per cent. to 10 per cent., the yield being quadrupled during this period as a result of the favorable temperatures and good rains. In the following months, seed shedding and defoliation were largely responsible for a progressive deterioration in quality, until by September the content of protein had fallen to 3.2 per cent.

Phosphorus showed the same trend, falling from .142 per cent. in September, 1935, to .082 per cent. in December, 1935. In response to the January rains it increased to .206 per cent, falling progressively thereafter to a value of .049 in September, 1936.

The changes in the content of fibre were the inverse of those recorded for nitrogen and phosphorus. The young green growth at the January cut contained 25 per cent. Rising rapidly with stage of growth, it reached a value of 35 per cent. by 10th March. These changes are reflected in the nutritive ratio, values of which are shown in Table 8.

TABLE 8.—SHOWING THE NUTRITIVE RATIO OF THE HERBAGE AT THREE STAGES.*

Date	18th February	8th April	23rd September
Ratio	1 : 7	1 : 9	1 : 33

* Approximate only—values obtained by computation from digestibility data given by Henry and Morrison.

Calcium showed no seasonal trend, remaining at a low figure throughout.

So far, the discussion has been confined to the grazed area, but the grazing was so light as not materially to affect the conclusions, the difference in composition between samples obtained from the two areas seldom being significant.

The species of *Astrebla* were separately analysed, because of their dominance in the pasture; the ungrazed samples were so treated from 21st January, 1936, and the grazed from 8th April. Details are to be found in Table 9.

TABLE 9.—COMPOSITION OF ASTREBLA SPP.—"ELDERSLIE," 1936.

Date.	Crude Protein.		Phosphorus (P).		Calcium (Ca).		Crude Fibre.	
	Grazed.	Ungrazed.	Grazed.	Ungrazed.	Grazed.	Ungrazed.	Grazed.	Ungrazed.
21.1.36	..	17·2	..	·202	..	·30	..	26·8
18.2.36	..	14·2	..	·181	..	·29	..	29·3
10.3.36	..	9·3	..	·143	..	·27	..	35·8
8.4.36	8·6	8·2	·140	·134	·29	·31	35·2	34·6
6.5.36	6·3	6·1	·108	·101	·27	·37	34·1	33·9
2.6.36	4·9	5·2	·082	·094	·31	·33	33·9	34·7
30.6.36	4·4	4·9	·071	·088	·29	·27	34·6	35·2
30.7.36	3·6	4·2	·062	·078	·26	·31	33·8	34·6
25.8.36	3·2	4·4	·060	·070	·34	·31	34·6	34·0
23.9.36	3·4	4·1	·061	·062	·32	·29	34·8	34·7

The differences in composition between *Astrebla* spp. and the corresponding composite samples were small. The composition of the other constituents of the pasture therefore could not have differed widely from that of *Astrebla* spp. Again, there was no significant difference in the composition of the grazed and ungrazed samples.

5. Discussion of Results.

The climatic conditions during the experimental period were particularly favorable, the summer rains being well above average. They were, however, rather late in onset, both November and December being dry. Exceptionally heavy rains fell in June, 1935, the total of 569 points being the heaviest June rainfall on record. July and August are normally dry months and were such in 1935.

The maximum yield was 18 cwt. per acre of oven-dry pasture—the equivalent of 20½ cwt. on a hay basis. (This is on the assumption of 12½ per cent. of moisture in normal hay.) The rate of growth during February and March was rapid and the peak production was reached approximately three months after the first rains. Growth virtually ceased some time in April or early May, because the data indicate a decline in yield after April, except for a slight increase in yield recorded for the period ending 30th June following a fall of 233 points towards the end of May, which decline becomes significant in August.

The difference in the yield level consequent upon the winter rains in June, 1935, and the yield level consequent upon the summer rains from January onward, is a feature of the data. This difference is well illustrated in Fig. 2, the yield being 1.30 cwt. per acre in October, 1935, whilst in September, 1936, it was 14.51 cwt. This difference is due to the fact that the summer-growing species—particularly the Mitchell grasses—respond poorly to winter rains, the small annual herbage species being the chief ones to do so.

At no stage during the experiment was the pasture outstandingly high in nutritive value. Throughout, the percentage of calcium was low, averaging about .35 per cent., as compared with 1.5 per cent. in the top-dressed natural pastures at the Waite Institute and Kybybolite, South Australia. While the content of calcium remained almost unchanged throughout, protein and phosphorus showed marked seasonal changes. The highest protein level of 17 per cent. recorded in the January cut is relatively low for young pasture. Thereafter, a progressively lower protein content was recorded, reaching the low level of 4 per cent. in September. A similar trend in the phosphorus level was found, the maximum percentage of 0.21 per cent. being low, whilst the minimum phosphorus level of .046 per cent. indicates a probable deficiency in phosphorus from September, 1936, until the recommencement of growth. The fibre did not fluctuate as markedly as was expected, the values being almost stationary for several months at about 35 per cent. The lowest value of fibre, viz., 25 per cent., was rather higher than is usually found in young green pasture.

The maximum yield of 18 cwt. of oven-dry matter was, under the circumstances, unexpectedly high, and the chemical composition of the herbage at this stage was reasonably good. It approximated closely

to meadow hay with respect to its protein and fibre content and nutritive ratio. The phosphorus and calcium contents, whilst adequate for nutrition, were, however, on the low side.

From April onward, progressive deterioration took place in the quality of the standing herbage. This deterioration affected both yield and chemical composition to a marked degree, and it is to be expected that this deterioration would be maintained until new growth takes place. Thus, if it were economically possible to harvest the whole of the April production, this would maintain in thriving condition two sheep per acre for twelve months. By September, the yield had declined to 14½ cwt. per acre, the content of protein and phosphorus to approximately half the April value, and the nutritive ratio to 1 : 33. The low level of phosphorus suggests that the stock would be on a negative phosphorus balance for several months. Martin and Peirce (2) have shown that definite signs of phosphorus deficiency occur in sheep on an experimental diet containing 0.6 per cent. phosphorus. Selective grazing by the flock may, however, tend to overcome this deficiency for some weeks.

6. Conclusions.

1. The maximum yield of herbage was equivalent to 1 ton of hay per acre.

2. Growth was active from January to April and thereafter practically ceased.

3. Rapid deterioration in yield and nutritive value of the herbage occurred from April to September.

4. Phosphorus and protein, whilst adequate for nutrition in April, were very low by September, and the data suggest that phosphorus was definitely inadequate for the maintenance of adult sheep from June onward.

5. Calcium was low in all cuts. This is associated with the dearth of legumes in the sward.

7. Acknowledgments.

The authors wish to thank the following gentlemen for their assistance in the conduct of the work:—Mr. R. A. King, manager of "Elderslie" station, for assistance in the selecting, fencing, and grazing of the experiment; Mr. G. H. Clarke, B.Sc., who, under considerable difficulties, made certain of the species identifications; and Dr. A. E. V. Richardson for originally instituting the project and for his constant help in its prosecution.

8. References.

1. Davies, Scott, and Fraser.—Coun. Sci. Ind. Res. (Aust.), Bulletin 83, 1934.
2. Martin and Peirce.—Coun. Sci. Ind. Res. (Aust.), Bulletin 77, 1934.

The Sterilization of Fruit Cases.

By G. A. H. Helson, M.Sc., and W. J. Bennett.†*

The rapid progress in the development of transport and intensive agriculture has resulted in a corresponding increase in the amount of damage to crops by various pests. Among these the depredations of insects upon fruit has increased greatly in recent years, and every avenue of control must be exploited to the fullest if the pests of the orchard are to be kept under control.

Sterilization of fruit cases is an important subsidiary method of controlling fruit pests, particularly if the cases are to be used repeatedly throughout the harvest season, or where they are to be returned to the orchards from the fruit markets, canneries, and packing houses.

While investigating the problem of the Oriental peach moth (*Cydia molesta* Busck) in the Goulburn Valley, Victoria, it was found that a single case may harbour as many as 12 to 24 cocoons of this pest, and just as many of the codling moth (*Cydia pomonella* L.). As these cases are used a large number of times throughout the harvest, and may be sent to a different orchard every time they are emptied, they form an excellent means for the dispersal of the pests, as well as harmful fungi. To overcome this difficulty, a sterilizer, through which the cases could be passed as soon as they had been emptied, was designed. If it is used, only those cases free from pests are returned to the orchards.

To be of any practical value, any such machine must fulfil the following conditions:—

(1) It must kill the pests.

(2) It must be economical to run.

(3) It must not damage the cases or warp the wood.

(4) It must be completely automatic, so that each case will receive exactly the same treatment.

(5) It must be capable of treating more cases per day than the cannery or packing house can empty.

The steam sterilizer described below and illustrated in Plate 5 was found to fulfil all these conditions. A plan and side elevation are shown in Figs. 1 and 2.

The sterilizer consists of a 16-gauge iron tunnel, the length of which may be varied according to the number of cases to be treated per hour. In this particular instance, where it was desired to treat 1,000 cases per hour, the length of the tunnel was 14 feet, and stood on a welded 2-in. by ¼-in. angle-iron frame with an overall length of 19 feet and a height above ground of 2 ft. 7 in. The tunnel is covered with four water-sealed, iron lids. Ample provision should be made for drainage from the lowest point of the tunnel so that rubbish and

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FIG. 1.—Plan of Sterilization Machine.

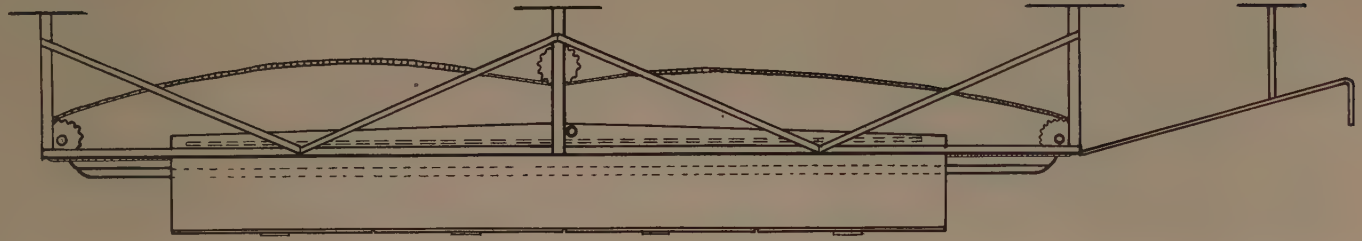


FIG. 2.—Side Elevation of Sterilization Machine.

water may be drawn away by a 3-in. pipe opening into an open drain. The frame supporting the tunnel is strengthened with 1½-in. by ¼-in. angle-iron stays; the legs are set on cement. Running from end to end of the frame and through the tunnel, are two endless pintle link chain belts (number 452) with right and left attachment links (number A12) every foot. A 14-gauge, ½-in. mesh, cyclone chain netting is attached to the chain which runs in two channel iron tracks made from 2-in. by ¼-in. flat iron, with sides of ⅜-in. by ¼-in. iron. The whole is driven by a ½-h.p. motor suitably geared to give 8 r.p.m. on a 1½-in. shaft which runs in ring-oiled plummer blocks. Fitted to this shaft are two 18-toothed sprockets, which engage in the link of the pintle chain. The speed of the chain is proportional to the length of the tunnel and is adjusted so that each case takes exactly one minute to pass through the machine. In this particular example the machine was designed to treat sixteen cases (22 inches by 15 inches by 10 inches) per minute, and the chain travels at a rate of 18 feet per minute. If, however, it is desired to treat 24 cases per minute, then the length of the tunnel should be increased to 21 feet, and the chain would then travel at a speed of 27 feet per minute.

In designing the height and width of the tunnel, allowance must be made for the variation in the size of the cases, and at least a 1-in. clearance allowed all around for the largest cases.

Live steam at 80 lb. pressure and a temperature of 310°F. is conveyed to the sterilizer by a 1-in. pipe, and is blown up into the inverted cases from a set of four or five 1-in. steam pipes with staggered outlets, whose combined areas are equal to the area of the cross-section of the steam pipe. In this way a temperature ranging between 170°–190°F., depending on whether the machine is run continuously or only at intervals, is maintained in the tunnel.

Tests with cocoons of *Cydia molesta* and *Cydia pomonella* proved that these are all killed after a one-minute exposure in the sterilizer. The force of the steam blowing into the cases penetrates into the corners and crevices where the pests spin their cocoons. The treatment does not damage the cases in any way, washes them clean, removes all rubbish, dries them quickly, and ensures that fruit is packed in cases free from pests.

A Soil Survey of the Horticultural Portion of the Mypolonga Irrigation Area (South Australia).

By R. L. Crocker, B.Sc., and B. E. Butler, B.Agr.Sc.**

Summary.

A survey has been made of the horticultural soils at Mypolonga (S.A.). The soils have been classified and mapped and include a new soil type and its varieties —Mypolonga sand. Four minor unnamed types have been also described. Portion of the area is highland which was under consideration by the S.A. Lands Department as an extension of the present settlement.

It was concluded that soils with more than 24 inches of surface sand overlying the stony or hard pan layer, commonly found in the major types, are suitable for all horticultural crops. The problems of high water table and salt accumulation are briefly discussed. Some analytical data on the soils are presented.

1. Introduction.

Mypolonga is a small irrigation settlement about 10 miles north of Murray Bridge and approximately midway between Murray Bridge and Mannum. Associated with the wide channel carved out by the Murray River at this point occurs an extensive swamp formation, which has been reclaimed and developed under pasture mainly for dairying purposes. The survey of this swamp was included in the investigation of reclaimed areas on the Lower Murray River by Taylor and Poole.† On the slopes above the swamps, where the steepness has not been prohibitive, the horticultural portion of Mypolonga, with which the present survey is concerned, has been developed.

The following horticultural crops have been planted‡:—

Crop.	Citrus.	Nectarines.	Peaches.	Apricots.	Vines.	Lucerne.
Area (approximate) in acres	338	20	67	125	107	289

The native vegetation of this area is very clearly defined. On the highland above the settlement, two mallees, *Eucalyptus dumosa* and *E. oleosa,* are the dominant trees, with spinifex, *Triodia irritans,* in isolated societies. On the more sandy ground, and on the slopes down to the swamp, the mallee gives way gradually to the Murray pine (*Callitris robusta*) and associated wattles (*Acacia* spp.). Towards the bottom on wetter and more saline soils, samphires (*Salicornia* sp.) frequently are the only plants.

The predominant rocks of the area are Miocene marine limestones, rich with characteristic Miocene (Janjukian) fossils. Limestone is undoubtedly the most important parent rock material.

* Officers of the Division of Soils, C.S.I.R.

† A Soil Survey of the Swamps of the Lower Murray River. J. K. Taylor and H. G. Poole, C.S.I.R. (Aust.) Bulletin 51, 1931.

‡ Annual Report, Dept. Lands (S.A.), 1936-37.

The average rainfall at Murray Bridge (30 years) was 14.03 inches, and at Mannum (40 years) 11.43 inches. The winter incidence of the rainfall is most marked, and very little rain falls in the summer months from November to March.

2. Soil Map.

All the rated horticultural land has been included in the survey, and in addition some 300 acres not at present irrigated, on the highland above the southern portion of the area. This was surveyed at the request of the Lands Department as a possible extension of the horticultural area and is included in blocks 820 to 835. The central portion of the area is known locally as the "basin". Certain blocks are non-rateable either because of stoniness or irrigation difficulties, e.g., blocks 796, 797, 798, 805, 806, 807; parts of 780, 786, 787. Towards the bottom of many blocks small portions, adjacent to the swamp, are not rated on account of their unsuitability for horticulture. In the lower part of the "basin" on either side of the salt drain, considerable areas have been excised owing to high water tables and accumulation of salt. These non-rated portions were not surveyed and consequently are shown blank on the soil map (p. 145).

3. Classification and Extent of Soil Types.

The predominant soil type differs sufficiently from those described on settlements higher up the river to warrant description under a new name, as the Mypolonga sand. It occurs generally throughout the settlement, but is particularly important in the southern part of the area. The stony variety of the Mypolonga sand is very extensive in the "basin". Several unnamed varieties of soils are of limited occurrence. There is a group of transitional soils towards the bottom of the slopes over practically the whole area.

The details of the classification, and the extent of the different soil types in the area surveyed, are as follows:—

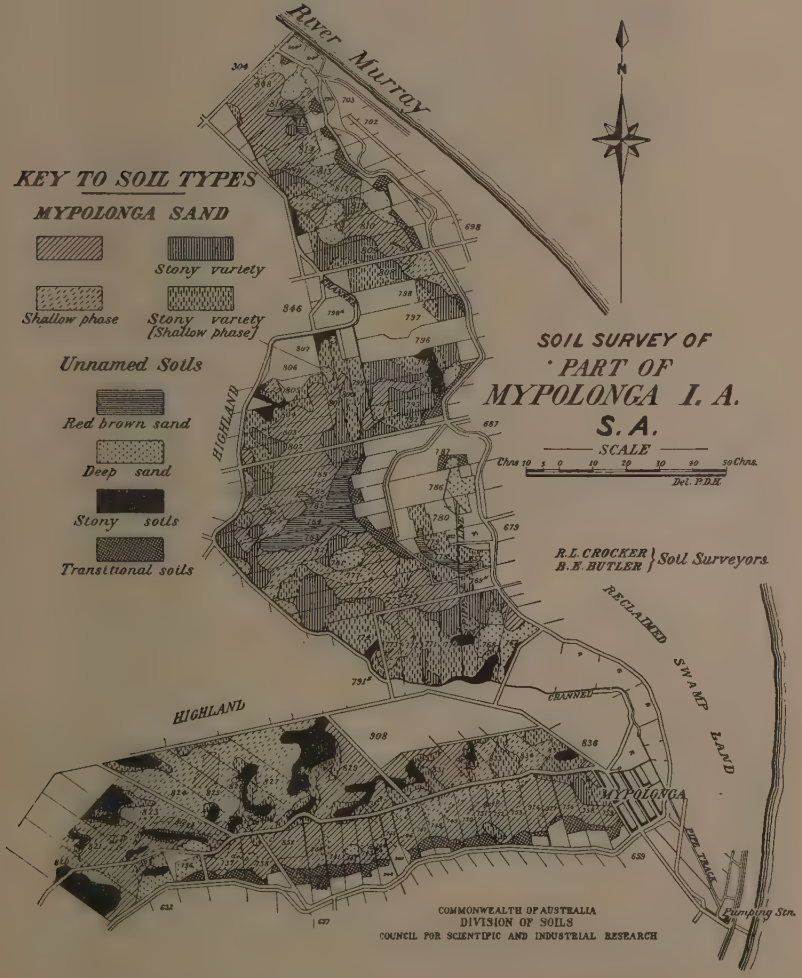
Soil Type.	Area (approx.) in acres.	Soil Type.	Area (approx.) in acres.
Mypolonga Sand—		Unnamed Soils—	
Normal type	429	Red Brown Sand ..	43
Shallow phase	186	Deep Sand	81
Stony variety (shallow phase)	226	Stony	87
Stony variety (deep phase)	139	Transitional Soils ..	63

Total area of all types surveyed—1,254 acres.

4. Description of Soil Types.

(i) Mypolonga Sand.

This is by far the most important soil type. The normal type has from 24 to 48 inches of brown sand, with variable lime rubble, over a slightly cemented marl pan of variable thickness, but usually less than 8 inches. Below this is an indefinite depth of slightly calcareous light brown sand which often extends to at least 10 feet. A shallow


River Murray
KEY TO SOIL TYPES
MYPOLONGA SAND
Stony variety
Shallow phase
Stony variety (Shallow phase)
Unnamed Soils
Red brown sand
Deep sand
Stony soils
Transitional soils
HIGHLAND
HIGHLAND
SOIL SURVEY OF
PART OF
MYPOLONGA I. A.
S. A.
SCALE
Chns 10 5 0 10 20 30 40 50 Chns.
Del. P.D.H.
R.L. CROCKER
B.E. BUTLER
Soil Surveyors
RECLAIMED SWAMP LAND
CHANNEL
MYPOLONGA
RIVER TRACK
Pumping Stn.
COMMONWEALTH OF AUSTRALIA
DIVISION OF SOILS
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

phase has less than 24 inches of brown sand over the marl pan. In several places on the soil map, such as blocks 752 and 775, a formation with more than 48-in. surface sand has been mapped as "deep".

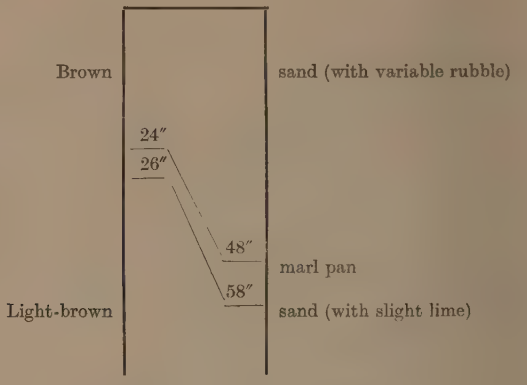


FIG. 1.—Mypolonga Sand (Normal Type).

Stony Variety.—A stony variety of the Mypolonga sand has also been defined. It differs from the normal type in degree of induration of the marl pan, which is much harder and more cemented. This variety has 24 to 48 inches of sand above the stony layer, which in turn overlies a slightly calcareous, weakly-cemented, light-brown sand. A shallow phase of the stony variety has 6 to 24 inches of brown sand over the stony layer.

(ii) Unnamed Soils.

A group of soils not sufficiently extensive to warrant particular names, but which are nevertheless distinctive, occur in the area surveyed.

(*a*) *A red-brown sand* mapped in the central part of the settlement has about 24 inches of brown sand overlying red-brown clayey sand, which occasionally approaches a sandy clay loam. A stony bottom which was not penetrable with the auger was reached in less than 6 feet. This soil, of which there is only a small area, is not well defined, but its slightly more clayey nature and its red-brown subsoil are sufficient to distinguish it clearly in the field from the Mypolonga sand.

(*b*) *Deep Sand.*—The deep sand formation showed slight profile development and included all loose brown sand with more than 60 inches of sand, without any evidence of marl pan or stone. It occurs widely, but rather irregularly, and is of more consequence at the northern end of the area.

(*c*) *Stony Soils.*—Limestone outcrops at the surface in several places. This stone is sometimes in the form of sheet limestone—perhaps a denuded pan of the stony variety of the Mypolonga sand, but at the other times it is continuous with depth. Areas with less than 6 inches

of sand over stone have been included in these stony soils. Stony areas occur chiefly in the area not at present irrigated in the southern part of the settlement.

(*d*) *Transitional Soils.*—Towards the bottom of slopes generally throughout the settlement there are rather complex formations where the sandy soils of the slopes give way to the typical heavy clays of the swamps. The soils of this transition zone vary according to the local predominating influence, and do not fall into any defined type. For the most part, however, they are greyish (in parts even black); they tend to be clayey in the subsoil but to a very variable degree, and very frequently have a water table near the surface.

5. The Relation of the Soil Types to Irrigation and Drainage.

The Mypolonga sand is the most attractive soil on the settlement for horticulture. The normal type including its shallow phase, and the deep phase of the stony variety, are particularly favorable to citrus. The marl pan is not prejudicial to plant growth, and offers little impediment to root penetration or water movement. Except where it adjoins the swampy land, drainage does not present any problems; indeed, the soil is so porous that it fails to hold the water as long as would be desirable and thus frequent irrigations, not more than four weeks apart, are necessary. Irrigation water is usually applied on a multi-furrow system, and, as vertical penetration of water in this sandy soil is so rapid, with very little lateral water movement, it would be profitable to bring one of the furrows close to the base of the tree. Spray irrigation which is practised on one citrus grove is a very effective method of applying water to these sandy soils. The sandy nature of the soil makes cultivation very easy at all times. Care is needed to avoid an extreme terracing effect between the tree rows, or the downhill drift of the soil.

It is considered that soils with less than 24 inches of sand over stone are of doubtful horticultural value. The effect of the shallow stony layer on root penetration is important. Blasting to fracture this layer frequently gives better results, but it is doubtful whether the expense is justified. On these soils stone fruits would do much better than citrus and possibly almonds best of all.

The red-brown sand type can be grouped with the Mypolonga sand, in so far as its reactions to irrigation and cultivation are concerned, but water movement in it is somewhat slower and on the lower slopes some water-logging has occurred.

The deep sand soils are also very similar to the Mypolonga sand but are still more porous, and are poorer in plant nutrients. However, these soils have been planted with citrus and irrigated with success. They require more extensive manuring, and in this respect manures supplying organic matter are of particular significance. The stony soils are of practically no horticultural value.

The transitional soils are generally unsuitable for horticultural crops, particularly on account of their liability to high water tables and to salt accumulation consequent upon the heavy absorption of water in the more sandy soils higher up the slope. Water-logging and salt are jointly the cause of unprofitable trees. Lucerne does well on the

TABLE 1.—MECHANICAL ANALYSES OF MYPOLONGA SAND.

Soil Type.	Normal.				Stony Variety (shallow phase).					Stony Variety (deep phase).			
Sample No.	5328.	5329.	5330.	5331.	5332.	5333.	5334.	5335.	5336.	5337.	5338.	5339.	5340.
Depth in Inches	0–9.	9 35.	35–42.	42–80.	0–6.	6–24.	24 30.	36 58.	60–80.	0 8.	8 27.	27–36.	48–60.
	%	%	%	%	%	%	%	%	%	%	%	%	%
Coarse sand	39·0	34·6	28·1	34·0	34·5	32·7	28·8	23·2	36·0	46·0	43·1	41·7	36·8
Fine sand	50·1	53·6	47·0	52·1	55·8	56·7	51·2	51·0	53·0	48·1	50·0	43·8	38·2
Silt	1·9	1·8	1·6	1·7	} 8·5	8·8	8·9	1·5	1·5	} 4·8	5·4	1·4	1·3
Clay	6·8	8·5	9·5	8·0				9·4	5·8			5·1	6·9
Loss on acid treatment ..	0·6	0·6	11·9	4·6	0·5	0·9	9·9	14·7	3·3	0·6	1·0	7·7	17·1
Moisture	0·9	1·0	2·9	0·9	0·7	0·9	1·2	1·1	0·7	0·5	0·5	0·8	1·3
Loss on ignition.. ..	2·2	1·6	6·4	2·9	1·7	1·4	5·4	7·2	2·2	1·3	1·1	4·1	7·9
Nitrogen	0·063	..	..	..	0·045	..	..	..	..	0·037	..	..	..
Total soluble salts ..	0·04	0·02	0·03	0·03	0·01	0·03	0·04	0·04	0·04	0·03	0·03	0·03	0·03
NaCl	0·006	0·003	0·005	0·002	0·002	0·001	0·005	0·009	0·004	0·002	0·004	0·004	0·002
pH	8·4	8·9	9·1	9·2	8·0	8·8	9·0	9·2	9·7	8·2	8·9	8·9	9·1

less salty patches of this soil type. Owing to the generally sandy nature of the soils, the trees on them probably have rather a low salt tolerance, and possibly the critical salt (NaCl) concentration is not more than 0.04 per cent. Of the small number of samples taken over the transitional soil zone, several showed a greater percentage of salt than this figure.

Water-logging.—The problem of removing excess water from the red-brown sandy soils and the transitional soils is rather difficult owing to their low elevation above the river and the consequent difficulty in finding a suitable outfall to facilitate drainage. The "basin" was at one time an old river overflow or billabong, and there is very little effective fall between it and the swamp. Using the open salt drains of the swamp area as an outfall, the maximum depth for internal block drainage appears to be about 3 feet in the basin section, where the problem is more acute. Wooden drains are used by some orchardists and are said to be more effective than tile drains, but the successful drainage of these soils seems almost impossible, without new means of removing drainage water to a depth greater than the present 3 feet. Where the land is not too salty, lucerne would help in keeping down the water table, and it may be necessary to use it as an intercrop if some of the trees now growing on the lower slopes are to remain healthy.

6. Analytical Data.

The analytical details of the type samples are given in Tables 1 and 2.

Table 2.—Mechanical Analyses of Unnamed Soils.

Soil Type	Red-Brown Sand.			Deep Sand.		
Sample No.	5341.	5342.	5343.	5344.	5345.	5346.
Depth in Inches	0–12.	12–45.	45–57.	0–12.	12–42.	42–75.
	%	%	%	%	%	%
Coarse sand	52·1	55·4	43·7	41·9	41·9	37·9
Fine sand	41·3	37·0	35·6	50·7	50·2	49·9
Silt	1·1	1·3	0·7	6·3	5·8	4·6
Clay	4·9	5·7	15·3			
Loss on acid treatment	0·2	0·2	3·9	0·6	1·4	6·9
Moisture	0·5	0·7	1·8	0·5	0·7	0·7
Loss on ignition	1·1	0·9	3·2	1·1	1·4	3·5
Nitrogen	0·021	..	..	0·031	..	..
Total soluble salts	0·02	0·02	0·04	0·02	0·03	0·03
NaCl	0·003	0·002	0·002	0·002	0·001	0·001
pH	8·4	8·4	9·1	8·4	9·1	9·2

All the soils are classed as sands, though there is some variability in the coarse sand to fine sand ratios. The red-brown sand is remarkably high in coarse sand considering the apparently more coherent nature of this soil in the field.

Soil reaction, as with all mallee soils, is strongly alkaline with a range for surface soil of pH 8.0–pH 8.4, and increasing to a maximum with depth to pH 9.1–pH 9.7 at about 4 feet.

Nitrogen was determined in the surface soils and is uniformly low, as was expected, particularly in the deep sand and red-brown sand. In consequence, green manure or other organic manures are essential for the maintenance of profitable production with all horticultural crops on Mypolonga soils; citrus probably requires additional inorganic nitrogen for high yields.

No estimations of other plant nutrients were made, but it is reasonably certain that the soils conform to similar types with low P_2O_5 and moderately high K_2O content. Superphosphate or other phosphatic fertilizer is necessary for the successful growth of green manure crops and is recommended also for application in the spring to vines and trees. There should be no need for the use of lime in any form as a fertilizer.

It is reported by some orchardists that the disease of mottle-leaf in citrus has been cured in their groves by the application of zinc oxide spray to supply a deficiency in the nutrition of the tree.

7. Acknowledgments.

The authors wish to express their thanks for the assistance of officers of the Lands Department, particularly Mr. G. E. Horner, of Mypolonga. They are especially indebted to Mr J. K. Taylor, Division of Soils, for his help and advice throughout

Fruit Bud Studies : The Sultana.

IV. Methods of Forecasting Yield.

By C. Barnard, D.Sc., and J. E. Thomas, B.Sc., B Agr.Sc., B.V.Sc.†*

Summary.

1. The yield of the sultana has been estimated at the commencement of the growing season on the basis of bud fertility, i.e., the percentage of fruitful shoots developed. In vines of average or sub-normal vigour, bud fertility appears to be the most important factor controlling yield, and forecasts of yield may be made with considerable accuracy. The estimate may not be so reliable with vines of extreme vegetative vigour, since low bud fertility may be compensated for by an increased bunch size and/or greater sugar development in the berries.

2. An approximate forecast of the yield for any vineyard may be made one season in advance. A method is suggested in which the basis of the estimate is the amount of crop matured during the previous season, and suitable allowances are made for any undue loss of potential crop which occurred during that season.

1. Introduction.

In the first article‡ of this series, attention was drawn to the fact that in the Mildura district there is a rather close relation between the proportion of fruit buds developed on the sultana vine and the resultant yield of fruit.§

Records of the proportion of fruit buds developed and crops harvested have now been obtained for vines during a period of eleven successive seasons at the Commonwealth Research Station, Merbein. These data have been used in conjunction with our knowledge of the components of yield, and of the relationships between yield, shoot growth, and fruit bud formation‖ to develop tentative methods of forecasting yield. In the present article, the factors which must be considered in making yield forecasts are briefly described, and an outline is given of the methods which are being developed at the Merbein Station.

The prime requisite for the development of any method of forecasting yield is an understanding of the principal components of the yield of the crop concerned. The yield components of the sultana are therefore discussed in the first section below.

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† An officer of the Commonwealth Research Station, Merbein.

‡ This *Journal* 5: (1), 47, 1932.

§ Except in the case of strictly biennially bearing varieties of horticultural fruits, little correlation is usually evident between the proportion of fruit buds and the resultant yield under conditions of commercial production. Seasonal fluctuations in yield are generally related to environmental conditions which affect the setting and development of the fruit rather than to variation in the number of blossoms produced. In the Zante currant, for instance, the proportion of fruitful buds never limits yield because practically all buds are fruitful; and in most varieties of apples, plums, pears, peaches, and cherries, the satisfactory set of quite a small proportion (3 per cent. to 6 per cent.) of the blossoms may result in a full crop of fruit.

‖ This *Journal* **6**: (4), 285-294, 1933; **10**: (2), 143-157, 1937.

2. The Components of Yield in the Sultana.

The yield of dried fruit in the sultana is dependent upon three main contributing components, viz., the number of bunches, the size of the bunches, and the sugar content of the berries. Since the majority of inflorescences are borne singly on the shoots, the number of fruitful buds may be used as a measure of bunch number; and further, as practically the same number of buds per vine are left on the one block of vines at pruning every season, the proportion of fruitful buds may be taken as a measure of the actual number of potential bunches. The number or proportion of fruitful buds is determined during the summer and autumn of the season preceding that in which the bunches are matured. Thus the first component, bunch number, is dependent upon factors operating during the previous season, and it has been shown* that one of the most important of these factors is the amount of fruit carried by the vine.

The second yield component, bunch size, is also related to conditions operating during the season previous to that in which the fruit is harvested. The potential size of the inflorescence is determined prior to bud burst in spring when flower differentiation occurs.† and it seems to be modified by the same factors as those which determine the number of inflorescences. From 70 to 80 per cent. of the flowers normally abscise, and though evidence on the point is somewhat meagre there does not appear to be very much variation in setting from vine to vine or from season to season.‡ Thus there is a fairly close relation between the size of the inflorescence and the size of the bunch developed therefrom in so far as the number of berries is a measure of bunch size. Early in the season the number of berries in a bunch is an accurate index of the size of the bunch. The ultimate weight of the bunch is, however, related to the vigour of the vine and the number of bunches which are carried. On vigorous vines or vines of normal vigour during a season when conditions are conducive to vegetative growth, the weight of the individual bunches at harvest tends to be high. Similarly, when a few bunches are developed, i.e., in years of low bud fertility, the average bunch weight tends to be greater than when a large number is matured. This compensating effect is generally due in part to increased berry size and in part to an increased sugar content of the berries. The more vigorous the vines the more marked is the compensation§, and in vigorous vines increased berry size is often the most important factor.

The sugar content of the fruit tends to be greatest when only a few bunches are matured. Further, an increased yield of fresh fruit may not result in a proportionate increase in the yield of dried fruit, because the sugar content determines the ratio of fresh to dried fruit,

* This *Journal* **10**: (2), 143-157, 1937.

† This *Journal* **6**: (4), 285-294, 1933.

‡ The following experiment, for instance, supports this view. Three treatments were applied, viz. (*a*) control, (*b*) 25 per cent. of the inflorescences removed during mid-October, and (*c*) 50 per cent. of the inflorescences removed on the same date; the treatments were replicated 30 times using 3 vine-blocks, and after setting 10 bunches were selected at random from each vine and berry counts were made. The differences in setting were small and not significant.

§ This *Journal* **10**: (2), 143-157, 1937.

i.e., the drying ratio.* Certain data suggest that the mean air temperatures during January are closely related to the accumulation of sugar in the berries.

3. Forecasting Yield at the Commencement of the Season (5-6 months ahead).

The foregoing brief analysis of yield components suggests that the number or proportion of fruit buds should provide a reliable measure of potential yield. Data collected during the period 1926-1937 from one plot of vines at the Research Station, Merbein, show that a very close correlation (excepting in 1927-28) exists between the percentage of fruit buds developed and the resultant yield. The correlation between bud fertility (i.e., the percentage of fruitful buds) and yield was $r = .877$, and the correlation between shoot fertility (i.e., the number of fruitful shoots expressed as a percentage of the total number of buds) was $r = .898$. The actual data are plotted in Fig. 1, together with the total annual production of sultanas in the district to the nearest 500 tons during the period 1926-1933.

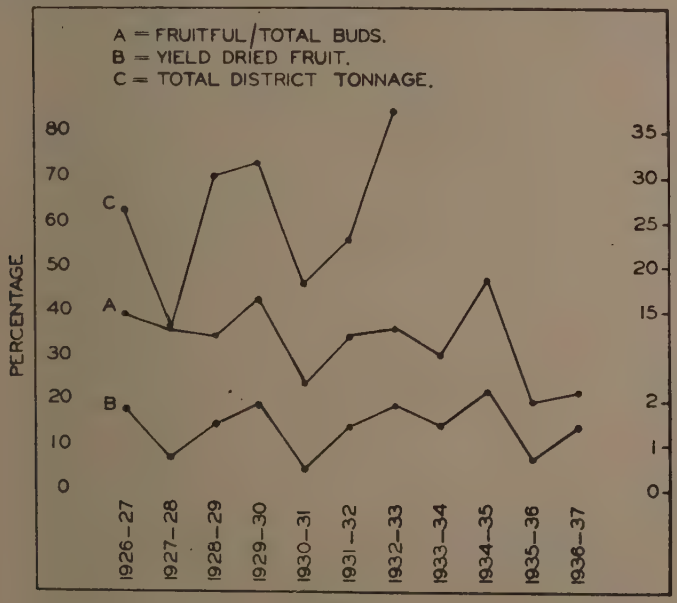

Fig. 1.

Except for the 1927-28 season, when crops were adversely affected by a very severe late frost, this graph shows a remarkably close correlation between the fruitfulness of the buds and yield. Though a considerable number of the buds failed to burst each season, the proportion which did form shoots was relatively constant. The dominant

* Typical tables relating to drying ratios to sugar percentages have been given by Walters. This *Journal* **10**: 116, 1937.

factor controlling yield is the percentage of fruit buds present. It would seem that on this site the combined effect of factors such as the incidence of disease, early mild frosts, hail, hot winds, and unfavorable weather conditions, generally resulted in a more or less comparable reduction in the realization of potential yield each season. Thus it is possible to predict yield with some accuracy shortly after bud burst occurs in spring and a determination of the proportion of fruitful shoots present has been made. A comparable determination could be made during winter by means of a microscopical examination of a representative sample of buds.

During the period 1926-33, the total yields of the district tended to be proportional to those of the Research Station. Since 1933, however, the same degree of parallelism has not been apparent. The plot of vines at the Research Station has not been so representative of the average vineyard in the district. Losses by hail, frost, and disease have been more irregular and sporadic, with the result that the bud fertility of many vineyards has become "out of step" with the vines of the Research Station. Further, many additional plantings have been coming into bearing. Nevertheless, it seems reasonable to assume that if comparable data to that obtained at the Research Station were recorded from a series of representative vineyards fairly accurate district forecasts should be possible.

Bud fertility forms a more accurate basis for forecasting yield for vines of medium vegetative vigour, such as those of the Research Station (which have a mean pruning weight of 7.0 lb.) than for very vigorous vines. In vines of extreme vegetative vigour a much more marked compensatory increase in the weight of individual bunches occurs when bud fertility is low and inter-annual fluctuations in yield are generally less than in vines of medium vigour. Data for bud fertility and yield on two blocks of vigorous vines are given in Table 1 to illustrate these points.

Table 1.—Bud Fertility and Yield in Vigorous Vines.

Season.	Block A.—Mean Pruning Weight 9·3 lb.		Block B.—Mean Pruning Weight 8·0 lb.	
	Bud Fertility.	Yield Dried Fruit per Acre.	Bud Fertility.	Yield Dried Fruit per Acre.
	%	Tons.	%	Tons.
1931–32 ..	50	2·05	..	..
1932–33 ..	42	2·50	..	..
1933–34 ..	42	1·80	35	2·73
1934–35 ..	44	Lost by hail	70	2·65
1935–36 ..	22	2·50	35	1·55
1936–37 ..	..	..	36	2·10

It will be noted that, though the bud fertility on Block A was low in 1935-6 as a result of the damage occasioned by hail in 1934, the yield of fruit was not proportionately low. The increased weight of the individual bunches entirely compensated for the low fertility. These observations indicate the necessity of making allowance not only for the vigour of the vine but also its previous history when forecasting yields.

4. Forecasting Yield 12 Months Ahead.

Because one of the principal factors controlling bud fertility is the amount of crop carried during the season when fruit bud formation occurs, a definite relationship between the crop of one season and the number of fruit buds developed for the following season might be expected. In Fig. 2 the harvest of one season from the vines at the Research Station is plotted against the shoot fertility of the next season. A casual inspection reveals little systematic relationship between the two variables. A graph representing an approximation

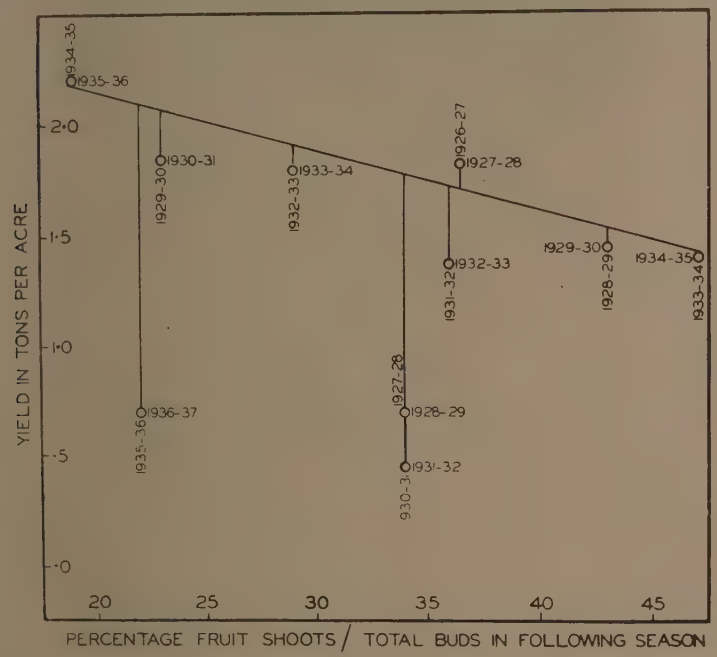

Fig. 2.

of the general relationship and showing the amount of deviation of the individual points has been superimposed on the diagram. The greatest deviations occur in the points for 1935-6/1936-7, 1930-1/1931-2 and 1927-8/1928-9, and it would seem that these irregularities render the relationship valueless as a basis for forecasting yield. A more detailed analysis of the data, however, shows that the deviations are quite systematic and capable of reasonable explanation. In Fig. 3 a scatter diagram is given of the bud fertilities and resultant yields for each season. Excluding 1927-8, the regression of yield on fertility is represented by the continuous line graph. The greatest realization of potential yield occurred in the seasons 1934-5, 1936-7, and 1932-3, and the broken line graph linking the points representing these seasons shows the realization of potential yield under the most favorable conditions. In 1927-8, the realization of potential yield was lowest. Realization was greatest in 1934-5, 1932-3, and 1936-7, with the other

seasons in the following order—1926-7, 1933-4, 1929-30, 1928-9, 1931-2, 1935-6, and 1930-1. The factors responsible for the differences in the realization of potential yield during the different seasons are believed to be mainly climatic. It is known definitely, for instance, that the principal limiting factor in the 1927-8 season was a severe late frost. The most interesting conclusion may be drawn from this graph, however, when it is compared with that of Fig. 2. It is apparent that, when seasonal conditions limited the realization of potential yield most markedly (Fig. 3), the formation of fruit buds for the following season was considerably less than the average associated with a crop

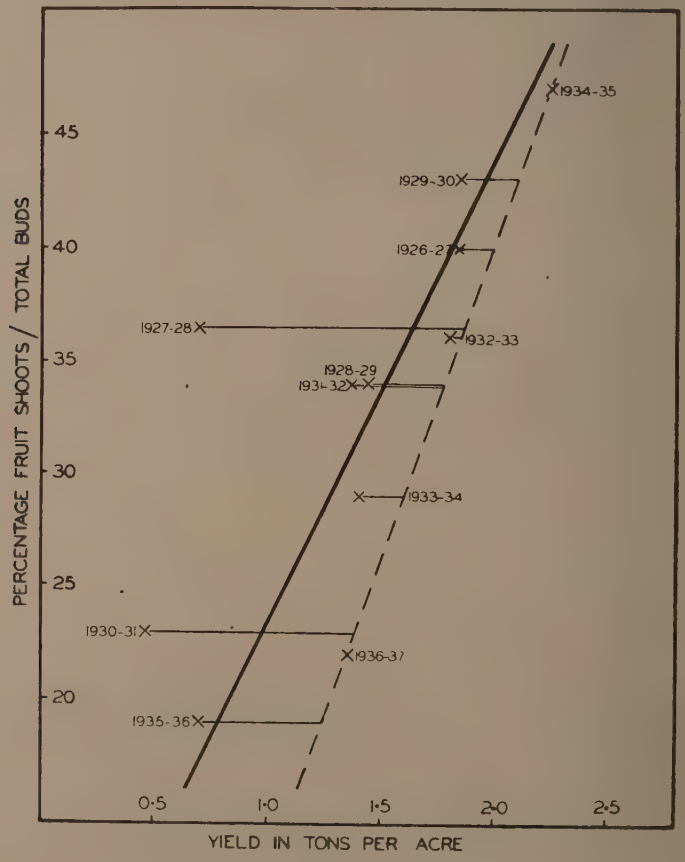

Fig. 3.

of the size which was carried. For instance, in 1927-8, 1930-1, and 1935-6, the realization of potential yield was low (Fig. 3) and the bud fertilities during the following seasons, viz., 1928-9, 1931-2, and 1936-7, were also abnormally low.

It has previously been shown* that under adverse conditions the vine tends to mature its crop at the expense of the maturation of the shoots and fruit bud formation. It is only to be expected, therefore, that, in seasons when the realization of potential yield is most markedly curtailed, fewer fruit buds for the following season will be developed than in seasons when the realization of potential yield is greater. Thus it will be apparent that the shoot fertility of one season may be estimated on the yield of the previous season if the amount of loss which occurred in the realization of this yield is also taken in account. The most satisfactory and practical way of making this estimate, however, is to use the potential yield of the previous season as the basis of the calculation. For this purpose the relations between the potential yield of one season and that of the following season must be known, and those data for the vines under investigation are set out in Fig. 4.

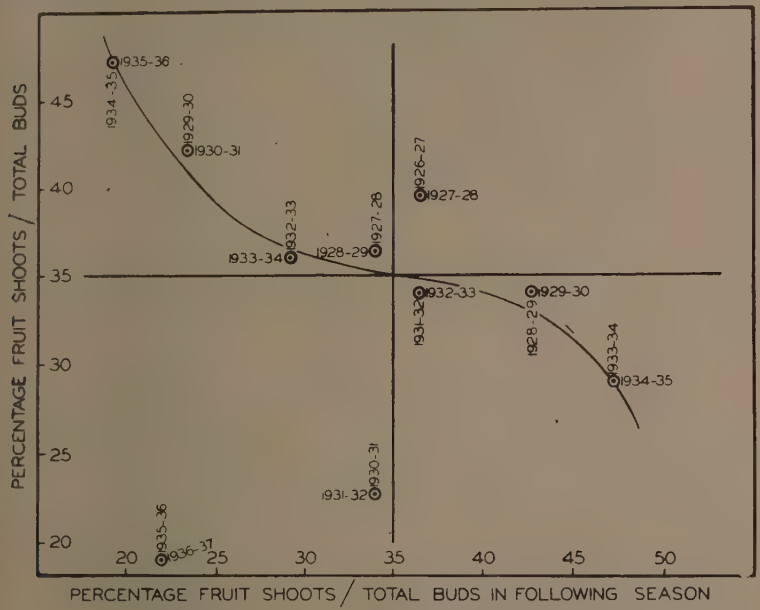

Fig. 4.

A general inverse relationship is evident, and with two exceptions the points can be covered by a freehand sigmoid curve intersecting at the 35 per cent. points of both axes. The two exceptions, viz., the low fertilities of 1936-7 and 1931-2, are explained by the fact that during 1935-6 and 1931-2 very heavy losses in the potential crop occurred (*vide* Fig. 3).

The sigmoid curve is interpreted as indicating that the carrying capacity of these vines under the existing system of cultivation and pruning is a crop such as is borne when 35 per cent. of the total buds produce fruitful shoots. When more shoots are fruitful, fertility is

* This *Journal* **10**: (2), 1937.

lower the following season, and vice versa. As soon as the bud fertility of one season is known (i.e. in September), the fertility of the following season may be estimated with a reasonable chance of approximating the actual value. By using the graph of Fig. 3, this estimate may be expressed in terms of potential yield, and a forecast of this kind is made 18 months before harvest. The more accurate prediction is made on the same basis but after the current season's crop has been harvested and allowance made, if necessary, for any loss in the realization of this crop.

There are obvious difficulties preventing the systematizing of such a procedure in formula form at present. In the first place, insufficient data are available regarding the relation of very low yields and subsequent shoot fertilities. In the second place, factors causing loss of yield may affect the crop only or may also injure the foliage and shoots. Under field conditions, foliage and shoots are usually damaged when adverse seasonal conditions, such as hail, frost, or hot winds, reduce the crop. The principal difficulty is that the effective agents causing loss of crop may occur at different times in different seasons. Data derived from disbunching experiments and other sources are slowly being accumulated, and ultimately it may be possible to make an allowance for the time at which the major loss in the realization of potential yield occurred and thus make more accurate the system of forecasting described above. Some of these data will be discussed in the next article of this series.

Another important relation which must eventually be incorporated in the formula for forecasting yield is that which exists between fruit bud formation and the mean air temperatures which obtain during the growing season. Perold* writes as follows:—

> "Marescalchi has carefully compiled the observations recorded on the weather and the size of the grape crops during the period 1855-1907 for the region around Monferrato in North-Western Italy, and concludes that the big crop was always obtained when the preceding year had been fairly warm and dry. A dry and mild (not cool) spring allows the young shoots and their eyes to develop well, and favours the formation of fertile eyes. A summer and autumn that are warm and dry, but not so much as to hinder the growth of the vines, allows the fertile eyes to develop well and ripens the wood well, with the result that the following crop will be heavy if it is not destroyed by hail or diseases, or if the previous crop had not already been a very big one. . . . .
>
> . . . . . According to Marescalchi we can with fair accuracy predict the size of the coming crop, even before the vines begin budding, by taking into account the weather conditions (heat and rainfall) during the preceding twelve months and the size of the preceding crop."

Rainfall is not of much importance in an irrigated district, but temperature does seem to play an important role in influencing fruit bud formation. The correlation co-efficients for the mean maximum temperatures during the growing season and bud fertility in the

* A Treatise on Viticulture, p. 568 (MacMillan and Co., 1927).

following year have been calculated for the vines at the Research Station during the twelve-year period 1926-37 and are shown as follows:—

Correlation bud fertility and the mean daily maximum temperatures during October-February (inclusive), $r = .680$; bud fertility and temperatures October-January (inclusive), $r = .673$; and bud fertility and temperatures October-December (inclusive), $r = .630$. In all cases the correlations are significant.

In conclusion, it should be noted that this article is merely an interim report of the investigations which are proceeding at the Research Station at Merbein concerning the problem of forecasting yield. The methods which are being developed are giving most promising results but so far are based on only twelve years' records. They do seem to indicate, however, that, as further seasonal records are added to the data in hand, it will ultimately be possible to forecast the yield of both individual vineyards and the district with a considerable degree of accuracy.

Fruit Bud Studies: The Sultana.

V. The Stabilization of Yield in the Mildura District.

By J. E. Thomas, B.Sc., B.Agr.Sc., B.V.Sc., and C. Barnard, D.Sc.†*

Summary.

Suggestions are made regarding methods for stabilizing the annual yield of the sultana vine:—

1. By pruning so that the potential crop each season approximates the carrying capacity of the vines, more even annual yields may be obtained in the sultana. Methods of estimating both the carrying capacity and the potential crop of a block of vines are described.
2. By light pruning and partial disbunching, the leaf fruit ratio may be increased. If the number of bunches removed is such that those remaining produce a crop equal to the carrying capacity of the vines, more even annual yields should result. Owing to the increased leaf fruit ratio the actual carrying capacity of the vines is also raised.

Experimental evidence in support of the above methods is presented.

1. Introduction.

The data presented in the previous article of this series‡ in connexion with the problem of forecasting yield in the sultana may also be used as a basis for discussing the question of obtaining more even

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‡ See page 151.

annual yields. The annual fluctuations of yield, shown in Fig. 1 of that article, are fairly typical of normal vines and also indicate the fluctuations which occur in the total district tonnages from season to season. Particularly low yields are occasionally caused by a loss of crop following severe late frosts or some other adverse seasonal conditions. The greater part of the variation in yield from season to season occurs, however, under apparently similar environmental conditions. Under irrigation, soil moisture conditions are more or less comparable each season. Other climatic factors vary from season to season, but tend to more or less balance each other so far as the effect on the plant is concerned. The bulk of the variation in yield has been shown to result from the inter-relation of successive annual yields, and this is particularly so in the case of vines of low to average vegetative vigour.

The carrying capacity of vines at the Research Station, Merbein, has been estimated as the crop which results when 35 per cent. of the buds produce fruitful shoots. Under normal conditions of cultivation and pruning, this crop is approximately equivalent to 1½ tons of dried fruit per acre. A smaller crop is associated with the formation of a higher proportion of fruitful buds for the following season, while a larger crop is accompanied by decreased fruit bud formation.

The percentage of fruitful shoots is really an approximate index of the leaf-fruit ratio. The leaf-fruit ratio corresponding with the yield capacity of the vine may safely be assumed to be fairly constant for the climatic conditions which prevail in the Mildura district, and within the range of pruning practised. The carrying capacity of all vines in the Mildura district estimated on the basis of the proportion of fruitful shoots is therefore probably comparable to that of the vines at the Research Station, viz., 35 per cent. fruitful shoots. The actual size of the crop which may be carried will, however, vary with the vigour of the vine and the number of buds it is able to carry. While the estimate on a crop basis of the carrying capacity of vines at the Research Station is 1½ tons of dried fruit per acre, the carrying capacity of a block of more vigorous vines would be greater and of a block of less vigorous vines lower. Thus the relationship between fertility and yield will differ with the vigour of the vines, and these differences will be greatest when either high fertilities occur on vines of low vigour or very low fertilities occur in vines of high vigour. In the latter case, increased bunch and berry size compensate to a marked degree.

It is obvious that, if even annual yields are to be maintained, methods of pruning and/or cultivation must be so adapted that the vines bear a crop equal to their carrying capacity every season. Means whereby such ideal cropping might be attained are discussed in this paper. Experiments on disbunching and pruning which are relevant to the problem under consideration are also described. These experiments give an indication of the extent to which loss of crop during the season may be compensated for by an increased development of the remaining bunches and also show the effect of disbunching on the fertility of the buds for the following season.

2. The Stabilization of Yield by Means of Pruning.

Recommendations as to when the yield of vines may be best increased by stimulating vegetative vigour or the same objective attained by leaving more buds at pruning have been made elsewhere.* The conclusion to which it is desired to draw attention at present is that pruning practice should aim at providing sufficient fruit shoots each season to produce a crop equal to the carrying capacity of the vines concerned. In order to do this, records must be kept of the shoot fertilities and yields each season in the same manner as has been done at the Research Station. By keeping records of the average number of fruitful shoots† and the yields each season, the grower may determine the actual carrying capacities of his vines. Further, by means of the yield records and the method outlined in section 4 of the previous article he could estimate approximately each season the proportion of fruitful buds present before pruning. The amount of wood left at pruning would depend upon this estimate. If it were forecast that a high proportion of the buds were fruitful, he would leave less wood than if a small proportion were expected to be fertile. The degree to which such a method could be refined would depend on the amount of data available concerning the vines. Quite frequently there is a tendency to leave least wood in those seasons when it would be advisable to leave more than usual. In seasons when a low proportion of fruitful buds are formed, a high proportion of immature wood is developed. In such instances, potential yield is definitely restricted by low fertility, and more buds should be left even although the wood appears to be of poor quality.

3. The Stabilization of Yield by Means of Light Pruning and Disbunching.

An alternative or perhaps complementary method of evening annual yields is by means of artificially controlling the leaf-fruit ratio. By lighter pruning than normal, more fruit buds and higher potential yields may be obtained. If the light pruning is followed by a thinning of bunches to such an extent that a crop of approximately the carrying capacity of the vines is matured, the effect would be to even annual yields. Moreover, it is quite likely that, since the leaf-fruit ratio would be increased, the actual yield capacity of the vines might also be increased.

The application of a comparable conception in viticulture has developed in California during recent years. In a series of experiments with the Muscat of Alexandria—a variety probably identical with the Gordo Blanco of Australia—Winkler‡ found that dormant pruning reduced the rate and total capacity for growth of both the leaves and shoots. As the amount of pruning decreased, the depressing effect of yield on growth became less. When cluster thinning was used in place of pruning to control the yield, the viability of the pollen increased and there was an increased number of berries set per bunch which resulted in a substantial increase in yield. There was a

* This *Journal* **10**: (2), 144-157, 1937.

† This involves counting the number of fruitful and barren shoots on a number of representative vines. A good estimate may be based on counts from about 50 vines selected at random. If the counting is done in early spring, it should not take more than a few hours to accomplish.

‡ Cal. Agr. Expt. Sta., Bull. 519, 1931.

considerable reduction in the number of small shot berries (i.e., *millerandage*), a fault to which this variety is subject, especially in humid climates. Winkler* suggested that these advantages were associated with an increased production of carbohydrates consequent on earlier and more rapid leaf development. It is of course impracticable to eliminate pruning altogether, so Winkler recommended the adoption of light pruning with subsequent cluster thinning prior to flowering as the best method of controlling yield.

The sultana is cane-pruned and is not subject to "coulure" under normal conditions. The adoption of Winkler's method could not be expected, therefore, to affect bunch size appreciably in this variety. Nevertheless, it might be expected that the increase in leaf-fruit ratio would tend to raise the yield capacity.

In order to adapt Winkler's method to suit the sultana vine in the Mildura district, it would be necessary to leave more wood than is usually the practice at present. An estimate would then have to be made in spring of the average number of bunches present per vine in each block. This would be done by counting a representative number of vines as suggested in the previous section. In years of high shoot fertility, the number of bunches would need to be reduced to what is considered a satisfactory number for vines of that vigour to mature, i.e., the carrying capacity of the vines. Naturally only block methods can be considered, as it would be impracticable to vary the number for each individual vine. The average number of bunches which it would be desirable to leave may vary from 25-40 per vine, depending on the average vigour of the vineyard. In years of low fertility, it would probably be unnecessary to disbunch at all. It is estimated that the cost of disbunching would be in the vicinity of 10s. to 20s. per acre

These suggestions are made primarily in connexion with vigorous vines. Where vegetative growth is weak, it is realized that the principal objective should be the increase of yields and yield capacity rather than the maintenance of even annual yields. The first step towards increasing the production in vines of subnormal vigour is to stimulate vegetative growth by means of improved cultural practices.

4. Disbunching and Pruning Experiments.

(i) Disbunching.

To obtain further experimental data regarding the possibilities and practicability of such a system of fruit thinning as described above, disbunching trials were carried out during the past three seasons. These experiments are useful in that they indicate the degree to which compensation in yield during the current season and in the shoot fertility of the following season may be expected as a result of limiting yield by disbunching.

In the first experiment, 100 vines were selected and divided into 50 blocks. The fruit from one vine selected at random in each block was removed shortly after flowering (November, 1934), while that on the remaining vines was harvested at the normal time (February, 1935). The effect of this treatment on the shoot fertility and yield of the following two seasons is shown by the data in Table 1. The removal of the bunches during one season resulted in an increased yield for the following two years. Approximately 40 per cent. of the yield lost by

* Cal. Agr. Expt. Sta., Bull. 519, 1931.

TABLE 1.—SUMMARY OF DISBUNCHING EXPERIMENTS.[1]

Season.	Treatment.	Bud Fertility.	Weight of Prunings.	Mean Bunch Weight.	Weight of Fresh Fruit.	Weight of Dried Fruit.	Mean Drying Ratio.
		%	lb.	lb.	lb.	lb.	
		Expt. 1. $n = 50$.					
1935–36	Control	20·9	2·54	·59	12·8	3·75	3·37
,,	Disbunched (in 1934)	26·5	3·12	·87	24·5	7·26	3·40
		(*s*)	(*s*)	(*s*)	(*s*)	(*s*)	
1936–37	Control	16·0	3·20	1·29	24·3	6·30	3·86
,,	Disbunched (in 1934)	17·0	4·20	1·37	27·9	7·48	3·73
		(*n.s.*)	(*s*)		(*s*)	(*s*)	
1937–38	Control	41·3	..	..	..	..	..
,,	Disbunched (in 1934)	43·0	..	..	..	..	..
		(*n.s.*)					
		Expt. 2. $n = 36$.					
1935–36	Control (*a*) ..	..	..	1·04	73	16·9	4·46
,,	25 per cent. bunches removed (*b*) ..	..	..	1·22	61	14·9	4·10
,,	50 per cent. bunches removed (*c*) ..	..	..	1·73	52	12·9	4·06
					a>*b*>*c*	*a*>*c*	
1936–37	Control (*a*) ..	34·3	5·99	} Yield lost owing to frost			
	(*b*) ..	37·1	5·92				
	(*c*) ..	41·3	6·77				
		c>*b*	*c*>*b*				
		c>*a*	*c*>*a*				
		Expt. 3. $n = 25$.					
1936–37	Control (*a*) ..	30·0	5·08	1·31	40·1	9·64	4·16
,,	Disbunched 4.1.36 (*b*)	34·5	6·31	1·38	51·4	11·92	4·31
,,	Disbunched 9.2.36 (*c*)	31·6	5·11	1·42	45·0	10·80	4·17
		b>*a*	*b*>*a*		*b*>*c*>*a*	*b*>*c*>*a*	

(1) Results examined by analysis of variance. n = number of replications; s = significant difference ($P < ·05$; *n.s.* = difference not significant; $a > b$ indicates that a is significantly greater than b.

disbunching was recovered in the enhanced yields of the subsequent seasons. The increased yield in the seasons following that in which disbunching was carried out seems to have been due to both increased shoot fertility and increased bunch weight. The sugar content of the fruit was not appreciably different from that of the controls. In addition to the effect upon bud fertility and bunch size, disbunching also resulted in more vigorous shoot growth.

In the second experiment, 108 vines were divided into 36 blocks of three vines each. From one vine selected at random in each block approximately 25 per cent. of the bunches were removed (*b*), from another approximately 50 per cent. were taken (*c*), while none were removed from the third (*a*). The disbunching was done prior to flowering on 24th October, 1935. A summary of the data obtained from this experiment is shown in Table 1 (Expt. 2). A particularly heavy yield was carried by these vines during the season of treatment.

It was equivalent to over 3 tons per acre, and although the vines were vigorous it would have been adjudged in excess of their carrying capacity. The average number of bunches carried by the control vines was 70; 50 bunches were harvested from vines of treatment (*b*), and 30 from vines of treatment (*c*). The yields were not proportional to the number of bunches matured, and approximately a 12½ per cent. recovery in yield was obtained in both disbunched series. This was apparently caused by an increase in bunch size and sugar content. The crops of the following season 1936-7 were unfortunately lost as a result of frost. The records of shoot fertility show, however, that both the 25 per cent. and 50 per cent. thinning resulted in increased bud fertility, and that the increase was most marked in the vines which had most bunches removed.

In the third experiment, complete disbunching was carried out at two different times, the first on 14th January, 1936, when the fruit was at a very early stage of maturity, and the second on 9th February, 1936, when the specific gravity of the juice was about 9° Baumé. Yield records for the following season were taken and these are summarized in Table 1 (Expt. 3). An increase in bud fertility resulted from both the January and February disbunching, and an increased yield was harvested in February, 1937. The increased yields were apparently due to the higher shoot fertilities and the better development of the bunches on the treated vines. The increase was much greater for the January harvested vines than for those harvested in February.

It will be seen from these three experiments that the removal of portion of the crop results in better bunch development and higher sugar contents during the year of treatment. More fruit buds are formed for the following season. A greater number of bunches and the better development of the bunches results in greater yields in the season following treatment. The later disbunching is carried out the less marked are its effects.

(ii) Combined Pruning and Disbunching Experiments.

The effect of disbunching vines, which were left with different amounts of bearing wood, was investigated in the following experiments. For the first experiment, a block of 300 vines upon which a manurial experiment in the form of a 5 x 5 Latin square was in progress was used. Each plot consisted of 12 vines, and the pruning and disbunching treatments were superimposed on the manurial experiment. The statistical analysis showed that there were no significant differences owing to the manurial treatments, nor were there any significant interactions between these treatments and any of the disbunching or pruning treatments. For the present purpose the manurial treatments may therefore be disregarded. The pruning treatments (*a*) and (*b*) and the disbunching treatments (i), (ii), and (iii) were applied at random to each plot, as shown in the accompanying diagram. During the

Diagram illustrating arrangement within one plot.

June of 1935, one-half of the vines according to the plan were pruned so as to leave approximately seven canes per vine (*a*) and the other half were pruned to approximately ten canes per vine (*b*). In the following season, 25 per cent. of the bunches were removed in early November from one-third of the vines (ii), 50 per cent. of the bunches were removed at the same time from another third of the vines in each group (iii), and the rest of the vines in each group were used as controls (i). The relevant records are summarized in Table 2.

The increased number of buds left under treatment (*b*) (ten canes) resulted in greater yields during both seasons than from treatment (*a*) (seven canes). The differences in yield were approximately proportional to the differences in the number of bunches. The higher yield carried by the vines of treatment (*b*) during the first season did not result in any decrease in the fertility of the buds for the following season. The leaf fruit ratio was approximately the same for both series of vines. It would seem, therefore, that the amount of crop borne by the ten canes was not in excess of the carrying capacity of these vines.

TABLE 2.—COMBINED PRUNING AND DISBUNCHING EXPERIMENTS.

Pruning only.

Treatment.	Mean No. of Buds.	Mean No. of Bunches.	Bud Fertility.	Shoots per Bunch.	Mean Bunch Weight.	Mean Yield Fresh Fruit.	Mean Yield Dried Fruit.	Drying Ratio.
			%			lb.	lb.	
1935–36.								
7 canes (*a*)	99	33	33	2·0	1·18	39	9·88	3·97
10 canes (*b*)	131	40	30	2·0	1·15	46 (*s*)	11·3 (*s*)	4·07
1936–37.								
7 canes (*a*, i)	118	32	27	3·2	1·68	54	11·22	4·82
10 canes (*b*, i)	151	36	24	3·3	1·81	65 (*s*)	13·63 (*s*)	4·72

Combined Pruning and Disbunching.

	Weight of Bunch (lb.).			Yield of Fresh Fruit (lb.).			Yield of Dried Fruit (lb.).			Weight of Prunings, 1937 (lb.).		
	a.	*b*.	Mean.	*a*.	*b*.	Mean.	*a*.	*b*.	Mean.	*a*.	*b*.	Mean.
1936–37.												
Control (i) ..	1·68	1·81	1·74	54	65	59·5	11·22	13·63	12·42	5·64	5·52	5·34
25 per cent. disbunched (ii) ..	2·12	2·25	2·18	51	61	56·0	11·38	14·13	12·75	5·52	5·24	5·38
50 per cent. disbunched (iii) ..	2·82	2·39	2·60	45	43	44·0	10·02	11·15	10·58	5·84	5·92	5·88
Mean ..	2·25	2·15	..	50	56	..	10·87	12·97	..	5·67	5·40	..

iii > ii, iii > i.

Standard Error of Difference in Yield of Dried Fruit.

a — *b* = ·485 lb.

i — ii — iii = ·740 lb.

The removal of 25 per cent. of the bunches did not appreciably affect the yield of dried fruit. The loss of potential yield involved in the reduction of the number of bunches was compensated for by the increased weight of the bunches remaining. Considerable compensation also occurred when 50 per cent. of the bunches were removed, but the net result was a significant decrease in the crop harvested. The recovery of yield in both instances was greater than that observed in the comparable experiment (No. 2) described in the previous section. This high degree of compensation is another indication of the fact that the amount of crop produced by ten canes was below that of the carrying capacity of the vines for the season.

No significant interactions between the treatments (*a*, *b*) and (i, ii, iii) are revealed by statistical analysis, yet it is interesting to note that the compensating increase in bunch size and total yield as a result of thinning appears to be greater in the vines carrying seven canes than in those carrying ten canes. The loss of crop in 1936 was followed by an increased growth and an increase in weight of prunings in the case of lightly pruned, heavily-thinned vines. It is also of interest to note that the disbunched and lightly-pruned vines (*b*, ii) and (*b*, iii) showed an increased bud fertility, although the treatments and interaction did not reach the level of significance.

In the second experiment, extremely light pruning was followed by disbunching, so that from 15 to 20 per cent. more bunches were left on the treated vines than were borne by the normally pruned controls. The disbunching was done in November, and this experiment was continued through four successive seasons. The relevant data are summarized in Table 3.

TABLE 3.—LIGHT PRUNING AND DISBUNCHING. (n = 35.)

Treatment.	Year.	Weight of Prunings.	No. of Buds.	No. of Bunches.	Shoots per Bunch.	Mean Bunch Weight.	Yield of Fresh Fruit.	Yield of Dried Fruit.	Drying Ratio.
		lb.				lb.	lb.	lb.	
a (control) ..	1933–34	..	119	42	1·80	1·57	66	15·3	4·32
b (treated) ..	„	..	250	68 (48)*	2·41	1·70	82 (*s*)	18·1 (*s*)	4·52
a	1934–35	7·83	115	83	..	·65	54	14·9	3·59
b	„	8·39 (*n.s.*)	205	110 (98)*	..	·62	61 (*s*)	17·7 (*s*)	3·47
a	1935–36	7·24	94	33	2·54	1·15	38	8·8	4·32
b	„	8·71 (*s*)	139	50 (38)*	3·06	1·18	45 (*s*)	10·9 (*s*)	4·13
a	1936–37	8·64	97	35	2·05	1·31	46	11·8	3·89
b	„	8·74 (*n.s.*)	180	49 (43)*	2·54	1·58	68 (*s*)	14·5	4·68 (*s*) (ii)

* After partial disbunching.

(ii) This high-drying ratio is probably due in part to mould loss following rain on the vines with the heavier foliage.

The effect of the treatment was to increase both the yields of fresh and dried fruit over the full period of four years. The percentage increase in yield of dried fruit was 18.3 per cent. the first year, 18.8 per cent. the second, 23.8 per cent. the third, and 22.9 per cent. the fourth. Yields were more or less proportional to the number of bunches. Some evidence of faulty development of the tips of the bunches was noted on the treated vines, although competent fruit graders could not distinguish between the grades of the dried fruit. The vegetative growth of the shoots was well maintained on the treated vines during the experiment, and, as a matter of fact, the significantly greater weights of prunings during the second and third seasons would seem to indicate that the increased leaf-fruit ratio of the treated vines had stimulated shoot development. No difficulty in obtaining renewal canes was experienced in the lightly pruned vines, as care was taken to leave spurs near the crown of the vine and all canes arising from this area were sharply kinked when wrapping to the trellis wires. In July, 1937, the vines of both series were cut back to approximately the same number of buds. The one-year-old wood was weighed after drying in a forced draught at 140°F. for 36 hours. There was a significant difference in the amounts of wood from the two series as is shown in Table 4 below. The greatest amount came from the treated vines.

These considerations seem to indicate that no cumulative weakening effects have accompanied the succession of heavier yields from the treated vines. In order to test this deduction by further means, two methods were used. The first was based on the findings of Legatu and Maumé* who state that over-production in the vine is accompanied by a diminution in the nitrogen content of the basal leaves of the fruit-bearing shoots. These investigators showed that regular differences of up to 100 per cent. occur in the nitrogen contents of such leaves from normally pruned vines and from vines carrying excessive crops as a result of under pruning. A composite sample was made of leaves on each of ten vines in each treatment, and twenty samples were examined by the methods recommended by Maumé, Dulac, and Bonatt.† The mean figures are shown in Table 4. There was no significant difference.

The second test was carried out as follows:—The twenty vines used in the previous test were sawn off at ground level during July, 1937, dried for ten days in a forced draught at 150°F., and weighed. Samples were taken of the trunks by collecting the sawdust obtained from approximately twenty saw cuts. The samples were ground to pass the 200 mesh sieve and extracted in an alundum thimble for sixteen hours with hot alcohol. The extracts were evaporated almost to dryness under reduced pressure, the residue taken up in water, and the total sugars estimated after inversion. For the starch determination the residue from the alcohol extraction was hydrolysed, with takadiastase and sugar determinations made by the Hanes‡ method. The mean results are summarized in Table 4.

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* *Compt. Rend. Acad. Sci.* **182**: 653, 1923.

† *Annal de l'Ecole Nationale d'Agric. Montpellier* **23**: (5), 1934.

‡ Hanes, C. J. *Biochem.* **23**: 29, 1929.

TABLE 4.—TESTS FOR STORED RESERVES.

Treatment.	Nitrogen in Leaves, 20th March, 1937. (n = 10.)	Weight of Annual Wood, July, 1937. (n = 35.)	Dry Weight of Trunk. (n = 10.)	Nitrogen in Trunk (per cent.) (n = 10.)	Total Sugars as Glucose. (n = 10.)	Starch as Glucose. (n = 10.)	Total Glucose.
	%	lb.	lb.	%	%	%	%
a (control) ..	1·34	5·27	14·3	0·48	4·6	8·9	13·5
b (treated) ..	1·36 (*n.s.*)	6·13 (*s.*)	17·6 (*n.s.*)	0·46 (*n.s.*)	4.4 (*n.s.*)	9·0 (*n.s.*)	13·4 (*n.s.*)

Percentages expressed in terms of dry weights.

There were no significant differences in the percentages of nitrogen or of carbohydrates, and the results support the view that the enhanced yields obtained by the light pruning and light disbunching treatment were not obtained at the expense of the stored reserves.

In conclusion, it is pointed out that the pruning and disbunching experiments described here indicate that the methods outlined in sections 2 and 3 regarding the stabilization of yield should be practicable and advantageous.

Stock and Scion Investigations.

I. The Problem and the Plan of Experiments at Stanthorpe, Q.

By B. T. Dickson, B.A., Ph.D., and L. A. Thomas, M.Sc.†*

1. Introduction.

This article presents a brief description of the rootstock problem and the progress of the experiments which have been undertaken on an area leased by the Council at a nominal rental in the Government Reserve at Applethorpe, Queensland. It is proposed to report, from time to time, the results of these experiments in further articles in this series.

The investigation in the first place was a co-operative one between the Council and the Queensland Committee of Direction of Fruit Marketing, and details of the arrangements made are to be found in previous issues of this Journal (*vide* **6**: 67, 1933, and **9**: 223, 1936).

During 1936, the three-year period, over which the Committee of Direction of Fruit Marketing was to contribute, expired and the Council assumed the responsibility for the conduct of the work.

2. The Problem.

Fruit growing, and especially apple culture in the Stanthorpe district of southern Queensland, is beset with many difficulties. In the case of apples, the general dwarf stature of the trees, their low yields, and their premature decline are mainly responsible for low and unsatisfactory returns to growers. The yield of apples in this district compares unfavourably with those obtained from many other fruit growing centres. For instance, the yield per acre in the Stanthorpe district averaged 41.6 bushels during the ten-year period 1924-34 and 53.0 bushels during the two-year period 1933-34; comparable figures for apple production in Tasmania were 149.6 bushels and 176.8 bushels, for South Australia 78.6 bushels and 90.0 bushels, and for Western Australia 72.0 bushels and 74.0 bushels. The present average yield per tree in a commercial and productive orchard in the Stanthorpe district is estimated at about 2 bushels per tree. Few growers obtain as many as 4 bushels per tree.

Climatically, the district seems suitable to the growing of apples, pears, plums, apricots, and small fruits. The rainfall averages about 30 inches per annum, with between 3 and 4 inches in each of the four summer months. The mean of the maximum temperatures for the year is about 70°F., with 80°F. in January, and 56°F. in July. Frosts occur almost nightly during the winter, as the elevation is 2,650 feet at Stanthorpe itself, rising to about 3,000 feet at summit. Generally, late severe frosts, which cause heavy loss during blossoming,

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are absent. With regular rains and moderate temperatures, the humidity is well maintained, and 9 a.m. readings throughout the year give monthly means of from 59 per cent. to 78 per cent.

Geologically and topographically, the Stanthorpe district is part of the New England Tableland, and the soils, though variable, are mainly granitic sands and so rather deficient in available plant foods. There is much evidence (1) to show that the soil is lacking in humus, nitrogen, and lime (2), and the potash content is about 5 per cent. but mostly unavailable. In physical properties the soils are generally satisfactory, for they are easy to work, retain moisture, and also on the whole drain well. It is apparent, however, that unless the fertility of the soil is not only maintained but augmented, trees cannot make good vegetative growth and produce satisfactory yields of fruit. Consequently, one phase of the problem of increasing average yields of good quality fruit per tree or acre in the Stanthorpe district is certainly that concerning soil fertility.

Another factor which probably contributes to the difficulty of growing satisfactory apple trees in this area is the use of what is believed to be an unsuitable type of rootstock. It is with this aspect of the problem that the investigations described hereunder are primarily concerned.

At the present time it is estimated that approximately 94 per cent. of the apple trees in the Stanthorpe area are on Northern Spy rootstock. This rootstock, which constitutes at least 90 per cent. of the plantings on the mainland of Australia, was adopted for general use some 40 years ago, primarily on account of its immunity to woolly aphis (*Eriosoma lanigerum* Hausm.). In addition to the advantage derived from its resistance to this pest, Northern Spy rootstock is also generally believed to induce scion varieties to early bearing and the production of good quality fruit. With the introduction of the insect parasite, *Aphelinus mali,* and the evolution of more effective spraying methods, woolly aphis has ceased to be a pest of major importance in established orchards, and immunity to woolly aphis is no longer an essential attribute of a satisfactory rootstock. Under these circumstances, the disadvantages of the Northern Spy type of rootstock have come more prominently into notice. The reputed disadvantages of this stock are:—that it forms a shallow and weak root system and produces a semi-dwarf tree; it is not entirely compatible with some commercial varieties; and it produces a tree which does not live as long under certain conditions of soil and climate as might reasonably be expected. There is, in fact, much evidence to support the view that this type of stock is not capable of producing long-lived trees under any but really favourable conditions of soil and climate, and that the premature decline of trees in many of our apple-growing centres is probably accentuated by its use. The adoption of a more vigorous stock type and one which is better suited to the average conditions of Stanthorpe might well contribute, in no small measure, to the solution of the problems in that district. The investigations which the Council is conducting are designed to discover such stocks, and, while the experiments are being carried out at Stanthorpe, it may also be reasonably assumed that the results which are obtained there will be of value to other apple-growing districts in Australia where

comparable conditions and problems occur. In this connexion, it may be noted that during the past five years the demand by growers, especially in New South Wales, for nursery trees grown on seedling in place of Spy stock has been increasing. There is very good reason for believing that more vigorous, long-lived, and productive trees are found on seedling stock than on Spy, and therefore this preference is to be commended. Seedling stocks vary, however, in their inherent and genetical characteristics, and consistent results may only be anticipated when vegetatively propagated rootstocks are used. The investigations at Stanthorpe are concerned mainly with the selection of the most suitable stock that may be so propagated.

3. The Programme of Investigations.

(i) *Apple Rootstocks.*—A programme for investigation at Stanthorpe was drawn up in November, 1933, and involved the following:—

(*a*) The importation of certain East Malling stocks.

(*b*) A survey of the existing rootstocks in the district, and the collection and propagation of such of these as had produced outstanding vigorous and heavy cropping trees.

(*c*) The importation of varieties known, or reputed, to be resistant to woolly aphis (at present Winter Majetin appears to be the only resistant stock other than Spy that has been used in Australia).

(*d*) A comparison of these stocks (*a*), (*b*), (*c*), together with Northern Spy and seedling stock under Stanthorpe conditions in preliminary nursery trials.

(*e*) A comparison by means of permanent field trials of those stocks which show promise in the nursery tests.

(*f*) The investigation of methods for propagating varieties on their own roots, (i.e., by means of cuttings, layering, stooling, &c.).

(*g*) The testing of the value of inarching trees with a very vigorous stock. The vigour and cropping capacity of trees may be increased by these means, and Malling stock No. XVI. was chosen as the most suitable for trial.

(ii) *Plum and Pear Stocks.*—While it is planned to concentrate effort, in the first place, on the apple rootstock problem, a programme for the investigation of plum and pear stocks has also been drawn up, and this involves:—

(*a*) The importation of certain pear and plum stocks from East Malling and elsewhere;

(*b*) a survey and selection of local plum and pear stocks;

(*c*) investigation of the methods of propagating these stocks in nursery trials;

(*d*) the investigation of the compatability of these stocks with the principal local scion varieties, the relative vigour of the stocks, &c., &c.

4. Progress Report of Investigations.

(i) *Apple Rootstocks.*

The above programme of investigation has been pursued with but little modification and a few additions since the inception of the experimental work in 1934. As the first step in the accomplishment of this programme, the following stocks were imported during April, 1934:—

300 No. XVI. East Malling.

20 each Nos. I., II., VII., XII., and IX.

20 each of four Merton Stocks (Spy x Doucin), Nos. 778, 779, 789, and 793.

These stocks were planted in rows for stool beds on land made available by Mr. St. J. Pratt of the Queensland Department of Agriculture at Stanthorpe. During the growing season 1934-35, the Malling and Merton stocks rooted satisfactorily; Malling No. II. rooted fairly and I., IX., XII., and XVI. well; of the four Merton stocks No. 793 rooted excellently, No. 799 well, and No. 789 poorly.

During the autumn of 1934 a map of the vegetation on the experiment area on the Applethorpe Reserve was prepared and a soil survey of 2 acres completed during the winter of the same year. This 2 acres was fenced and made into a nursery area. Sufficient stocks were obtained of all East Malling varieties from the stool beds for experimental work, and these were transplanted to the nursery area at Applethorpe during July, 1935

Investigations along the lines indicated in item (i) (*b*) of the preceding section were commenced during the winter of 1934, and a report on these studies has been published (3). Nine stocks of local origin were selected for further investigation.

In conformity with the programme under item (i) (*c*), the following varieties (in addition to the Merton stocks) reputedly immune to the attacks of woolly aphis were imported from England during January, 1935:—Ben Davis, Emperor, Alexander, Duchess of Oldenburg, Transparent de Croncels, Zuccamaglia, Reinette, Niedwetzkyana, Lady Carrington, Kirks, and Allsop's Early. Supplies of Ivory's Double Vigor stocks were obtained during 1935. All these stocks were propagated in the nursery area during the 1936 season.

Stocks of Northern Spy and seedling Pomme de Niege were set out and propagated in the nursery during 1935.

Preliminary trials in the propagation of varieties on their own roots (item (i) (*f*)) were commenced during 1934. Cuttings of one-year-old wood of Delicious, Granny Smith, Jonathan, Marjorie Hay, and Mona Hay were stooled. Satisfactory rooting was obtained only in the last two varieties (50 per cent. and 60 per cent. respectively). During the winter of 1934, scions of some 20 varieties were root-grafted, and during the summer of 1935 these were mound-layered to determine whether any of the varieties respond to this form of propagation. During the 1935-36 season layer beds were established of some 30 varieties for the production of trees on their own roots. A more detailed report of these experiments will constitute the second article of this series.

In pursuance of the proposal noted under item (i) (*e*), trees were selected in ten orchards in different parts of the district, and, using one tree in every five as a control, East Malling stocks No. XVI. were planted alongside the trees for inarching tests during July, 1934. Some of these were inarched during October of the same year, but, as owing to the change from one hemisphere to another involved in the importation of the stocks, growth continued well into the winter of 1934 and commenced very late in the following spring, most of the stocks were allowed one season's growth in the field before grafting. Records of tree growth were taken last season, but no results from this experiment may be expected for several years.

During the seasons 1935-36-37, observations were made on the growth and behaviour of all stocks in the nursery bed; the present position as regards item (i) (*d*) is that sufficient material has now been propagated for five nursery trials which have been set out as follows:—

Trial A.—Malling No. XVI., Spy, and Merton Nos. 779, 789, and 793, together with local stocks D and E, were budded to Jonathan during February, 1936, and now stand as two-year-old trees.

Trial B.—Thirty each of Spy and two local stocks, S4 and K, were budded whilst on the stools in February, 1936, and planted out when cut from the parent stools in July, 1936. These trees are now in their second year.

Trial C.—Forty each of stocks Merton Nos. 779, 788, Spy, Lady Carrington, Ben Davis, Allsop's Early, Zuccamaglia, and Niedwetzkyana were set out in randomized blocks in July, 1936, and budded to Jonathan in February, 1937.

Trial D.—Forty each of Spy, local stocks D and E, Malling XVI. and I., were lined out in July, 1936, and budded to Delicious in February, 1937.

Trial E.—The purpose of this trial is to discover, if possible, suitable intermediate stocks for Gravenstein, a variety which suffers from main trunk twist or gnarl. The understock is Malling No. XVI., and on this seven intermediate stocks have been worked. These intermediate stocks have been budded to Gravenstein at a height of 15 inches from the union.

Trial F.—Is also an additional trial to those previously planned and aims to obtain information on the effect of using certain varieties as intermediate stocks. Two hundred Malling No. II. stocks were budded to the following varieties during February, 1937:—Scarlet Permain, Nickajack, Duke of Clarence, Dunns, Reinette du Canada, Emperor, Alexander, and Delicious. All these, with the exception of the last named, will be used as intermediate stocks and will have Delicious budded upon them.

Main Trial.—Fifty each of the stocks Malling XVI., XII., II., and I., Spy, and Seedlings, Pomme de Niege were budded to Jonathan, and 50 each of the stocks Malling XVI., XII., and II., Spy, and seedlings of Pomme de Niege were

budded to Granny Smith during February, 1936, and now stand as one-year-old trees in the nursery. A further area on the reserve is being cleared and prepared during the present season for planting out this treal.

A survey has also been made and material collected of the scions of the principal apple varieties in the district. At present, a number of strains exist of the apple varieties in use, particularly in the case of Jonathan and Delicious. The survey should prove of some value in standardizing scion varieties, and will also allow of the selection of uniform scion material for the rootstock trials.

(ii) *Plum and Pear Stocks.*

The folllowing series of plum and pear stocks were imported from East Malling during January, 1935:—

Plums.—Myrobolan B, Pershore, Brompton, and Common Mussel.

Pears.—Nos. C_2, C_6, C_7, D_3, and D_4.

Layer beds of these stocks were established during 1935-36. The percentage of rooted shoots obtained from the plums was disappointingly low. Pershore, which is difficult to propagate in England, behaved similarly under Stanthorpe conditions—only 10 shoots out of 41 rooting. Brompton gave 25 rooted shoots out of 47 and Common Plum 9 out of 39. Since these stocks were imported it has been shown elsewhere that Common Plum is a dwarfing stock, and that on the whole Pershore is a better stock than Brompton. Having these considerations in mind and also taking into account the fact that Myrobolan B is the best stock for English plums in England and is easily propagated from cuttings, it is planned to discontinue investigations with all of these types except Myrobolan.

During 1934 and the following seasons, root cuttings were collected from the best pear and plum trees in the district. The first of these were planted in nursery rows for stool beds during 1935. So far four selections have been made from the pear stock series.

(iii) *Other Investigations.*

The investigation of other problems in the Stanthorpe is being prosecuted as time and opportunity permit. Experiments which have demonstrated the value of the application of lime under certain conditions have already been completed (4) and nutritional work by means of the tree injection method has been commenced.

5. References.

1. Brünnich and Patten in Publn. No. 243, Queensland Geol. Survey, pp. 139-142, 1914.

2. This *Journal* 9: (3), 235, 1936.

3. This *Journal* 9: (3), 233, 1936.

4. This *Journal* 9: (3), 235-236, 1936.

Stock and Scion Investigations.

II. The Propagation of Own-rooted Apple Trees.

*By L. A. Thomas, M.Sc.**

Summary.

Some 32 apple varieties were layered to produce own-rooted trees. By using this method practically all varieties gave a commercial yield of trees as compared with the yield of the commonly used Northern Spy rootstock.

1. Introduction.

Of late years, great interest has been aroused in regard to the most suitable choice of rootstocks for apple trees, and investigators have largely followed along traditional lines in using budded or grafted trees for experimental work. The performance of own-rooted apple trees has not been extensively investigated, and it has been suggested by Hatton (4) "that the initial difficulty in raising and the length of time necessary to encourage many varieties to take root, together with their slow development in the early years when so rooted, have combined to make budding and grafting an established practice."

The general difficulty in obtaining own-rooted apple trees is reflected in the methods used for their production. Ordinary stooling and layering methods have, up to the present, given poor results. Shaw (8) used the nurse-root method, whereby a scion of the desired variety has a piece-root grafted to it. The piece-root "nurses" the partially buried scion until sufficient scion roots are formed, generally after two years' growth in the nursery, when the trees are dug and the "nurse" root cut off.

A similar method of producing own-rooted trees, but with the "nurse" root-grafted in the inverted position, was tried by Roberts (7). He suggested that the method may have possibilities as a means of securing scion-rooted trees. Kerr (5) used this method on a larger scale with apples and plums, and after two years' growth in the nursery satisfactory scion roots were formed.

A further variant of the nurse-root method used by Maney (6) for producing own-rooted trees, is that whereby the graft union is wrapped with two turns of copper label wire. Roots appear above the constricted union, and it is suggested that the method may have commercial possibilities for free-rooting varieties.

A different method has been employed by Gardner (2). Instead of etiolating shoots by covering their bases with earth as in layering, young shoots on apple trees were covered as near their growing point as possible, with black insulating tape, or else, black paper tubes were tightly fastened over the ends of shoots in late winter, in such a manner that the new growth could push its way through the tube and emerge gradually into the sunlight. The shoots etiolated by these means were treated as ordinary cuttings in the following spring. Their rooting response varied from 30 to 100 per cent., depending upon the variety.

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In the Stanthorpe district within the past five years, root-grafted trees have been planted deeply, with the union well below soil level, with the intention of encouraging scion rooting. As very little is known concerning the degree of scion rooting induced, the type of root system formed, the depth of penetration of roots, and the performance of such trees when compared with those on standard rootstocks, a study of certain apple varieties on their own roots has been initiated. At the same time, the opportunity was taken to examine the rooting ability of certain apple varieties reputedly immune or highly resistant to woolly aphis attack, in an endeavour to find a rootstock possessing better qualities than Northern Spy.

2. Material.

The material used was partly local and partly imported. Varieties marked thus * in Table 1 were obtained as one-year-old trees on Malling XVI. rootstock from East Malling in January, 1935. These trees had a short growing season until mid-winter and were transplanted into permanent layer beds in July, 1935. All other varieties were one-year-old root-grafted trees on Northern Spy roots and were planted for layering in July, 1935.

3. Method of Propagation.

The method used is that called layering or mound layering by nurserymen. This method has been used successfully by Hatton (4) at East Malling for varieties which root readily. The trees to be layered are planted at an angle of 30 degrees to the ground level in order that the shoots can be pegged down horizontally without breaking them. The one-year-old shoots were pegged down by means of pieces of bent wire (No. 8 gauge fencing wire) or wooden stakes. When shoots from the layered stems had grown to a height of 3 inches, soil to the depth of 1 inch was drawn round their bases. As growth proceeded, more soil was mounded about the shoots until 10 inches of the bases of the shoots were covered. The layer beds were opened as late as possible in the winter, as root growth appeared to proceed almost continuously, though slowly, in the layer beds.

It will be observed that the trees were planted and produced rooted shoots on the layers in the one year. This is contrary to general nursery practice, where the trees are usually allowed to grow for one season before layering. But the method used is possible under Stanthorpe conditions, as the soil is a well-drained sand and the normal summer rainfall is sufficient for such a method to be carried out successfully.

It was found to be inadvisable to use freshly cut bush timber for stakes in pegging down the layered shoots, as *Armillarea mellea* developed in a layer bed of the variety Granny Smith. Thereafter wire pegs were used exclusively.

The young shoots of certain varieties, notably Delicious, Granny Smith, and Frampton were susceptible to heat injury. At ground level all tissues external to the xylem were killed and the shoots wilted and died. To prevent this, it was found necessary to break up the surface of the soil around the shoots, especially the hard crust which formed after rain, or else to spread a thin coating of loose soil around the shoots.

4. Results.

The results for the two seasons 1935-37 are set out in Table I. The percentage of rooted shoots suitable for transplanting is shown in column four. The average number of shoots obtained from each layer over two seasons (shown in column five), is a guide to the productiveness of the layer beds; and in most cases the productivity compares favourably with that of the commonly used Northern Spy rootstock.

A short description is given of the one-season-old root systems of each variety, to indicate their appearance at the transplanting stage. This is supplemented by photographs of root systems of chosen varieties in Plates 6 and 7. Only small numbers (50) of most of the varieties have been transplanted, except in the case of Delicious, where 150 have been planted out. As no trees have died following transplanting, it is thought that the root systems are strongly enough developed in one season to withstand this operation.

Particular attention was paid to the aspect of woolly aphis infestation in the layer beds. Certain of the varieties used were described as possessing "immunity" towards woolly aphis by Crane and others (1). In their communication the word "immune" refers to varieties "which are not attacked under natural conditions, but some of which may be slightly attacked when tested under the rigorous conditions of the greenhouse." Thus the varieties Ben Davis, Transparente de Croncels, and Jonathan, which they list as "immune," were attacked under open air conditions at Stanthorpe. Similar evidence in regard to the breakdown of immunity of particular apple varieties towards woolly aphis is recorded by Greenslade (3).

TABLE I.

Variety.	Year.	Number of Shoots.	Percentage of Rooted Shoots.	Average Number of Rooted Shoots per Layer for Two Years.	Remarks on Rooting and Woolly Aphis Attack.
Adams' Pearmain ..	1937	106	99	..	Rooting good; many fleshy roots
*Allsopp's Early ..	1936	40	100	18·6	Rooting fair; thin hard roots, little fibre. Severely attacked by woolly aphis
	1937	109	100		
*Ben Davis ..	1936	70	100	17·1	Rooting very good; abundant long thin hard roots; slightly attacked by woolly aphis
	1937	135	100		
Boswell	1936	43	95	6·2	Rooting fair; few thin hard roots, very little fibre
	1937	82	96		
*Bramley's Seedling	1936	16	100	17·0	Rooting very good; thick coarse hard roots, fibre plentiful
	1937	35	100		
Crofton Pearmain ..	1937	10	100	..	Rooting good; many thin hard roots, medium amount of fibre
Delicious	1936	75	100	10·0	Rooting good; coarse hard roots, little fibre
	1937	155	100		
*Emperor Alexander	1936	38	66	7·2	Rooting fairly poor; mostly thin hard roots, fair amount of fibre
	1937	54	87		
Foster	1936	45	88	..	Rooting fair; few thin hard roots, little fibre
	1937	79	83		

TABLE I.—*continued.*

Variety.	Year.	Number of Shoots.	Percentage of Rooted Shoots.	Average Number of Rooted Shoots per Layer for Two Years.	Remarks on Rooting and Woolly Aphis Attack.
Frampton ..	1937	81	100	..	Rooting good; abundant fleshy roots
*Golden Delicious ..	1936	6	100	16·0	Rooting fairly poor; few fleshy roots
	1937	10	100		
Granny Smith ..	1936	..	..	..	Rooting poor; few fleshy roots; attacked by Armillaria mellea
*Gravenstein ..	1936	6	100	20·0	Rooting good; thick coarse roots, fair amount of fibre
	1937	14	100		
Jonathan	1936	34	100	9·6	Rooting good; hard coarse roots, fair amount of fibre
	1937	57	100		
King Cole ..	1936	19	95	..	Rooting good; thin hard roots, little fibre
	1937	46	96		
*Kirk's	1936	19	95	10·3	Rooting good; thin hard roots, with much fibre
	1937	45	95		
*Lady Carrington ..	1936	80	100	15·1	Rooting fair; mostly thin hard roots, little fibre
	1937	165	100		
Laxton's Superb ..	1936	33	100	9·0	Rooting good; thin hard roots, practically no fibre; severely attacked by woolly aphis
	1937	52	92		
Madino	1936	21	100	6·7	Rooting very good; stools readily; abundant fleshy roots; susceptible to woolly aphis
	1937	39	100		
Marjorie Hay ..	1936	13	100	8·0	Rooting very good; stools readily; abundant fleshy roots
	1937	30	100		
McIntosh Red ..	1936	9	100	9·5	Rooting fair; few fleshy roots; attacked by woolly aphis
	1937	29	100		
Milton	1936	7	85	7·3	Rooting fair; few fleshy roots; attacked by woolly aphis
	1937	16	100		
Mona Hay ..	1936	24	100	9·1	Rooting good; abundant fleshy roots
	1937	58	100		
*Niedwetzkyana ..	1936	77	100	14·1	Rooting very good; coarse hard roots with abundant fibre; slightly attacked by woolly aphis
	1937	93	100		
*Northern Spy ..	1936	47	98	15·2	Rooting very good; mainly fleshy roots
	1937	108	98		
Peasgood	1936	16	94	9·5	Rooting fair; mostly fleshy roots; severely attacked by woolly aphis
	1937	25	92		
*Reinette Zuccamaglio	1936	67	98	17·8	Rooting very good; thin hard roots with medium amount of fibre
	1937	140	93		
Stayman's Winesap	1936	15	66	4·8	Rooting poor; few fleshy roots
	1937	30	80		
Stewart's Seedling ..	1936	41	90	11·9	Rooting fair; few thin hard roots
	1937	107	99		
*Transparente de Croncels	1937	51	100	..	Rooting fair; fleshy roots; attacked by woolly aphis
Widdup	1936	9	100	6·3	Rooting very good; fleshy roots; badly attacked by woolly aphis
	1937	16	100		
*Winter Majetin ..	1936	54	68	12·7	Rooting fair to poor; few thin hard roots with scanty fibre
	1937	116	80		

5. Literature Cited.

1. Crane, M. B., Greenslade, R. M., Massee, A. M., and Tydeman, H. M.—Studies on the resistance and immunity of apples to the woolly aphis, *Eriosoma lanigerum* (Hausm.). *J. Pomol. Hort. Sci.*, 14: 140, 1936.

2. Gardner, F. E.—Etiolation as a method of rooting apple variety stem cuttings. *Proc. Amer. Soc. Hort. Sci.* 34: 323-29, 1936.

3. Greenslade, R. M.—Horticultural Aspects of Woolly Aphis Control together with a Survey of the Literature. Imp. Bureau Fruit Prod., Tech. Comm. 8, 1936.

4. Hatton, R. G.—The relationship between scion and rootstock with special reference to the tree fruits. *J. Roy. Hort. Soc.* 55: 169-211, 1930.

5. Kerr, W. L.—A simple method of obtaining fruit trees on their own roots. *Proc. Amer. Soc. Hort. Sci.* 33: 355-7, 1935.

6. Maney, T. J.—The propagation of own rooted apple stocks. *Proc. Amer. Soc. Hort. Sci.*, 211-17, 1925.

7. Roberts, R. H.—Some stock and scion observations on apple trees. Univ. of Wisconsin Agric. Expt. Sta., Res. Bull. 94, 1929.

8. Shaw, J. K.—The propagation of apple trees on their own roots. Massachusetts Agric. Expt. Sta., Bull. 190, 1919.

The Influence of Phosphatic Fertilizers on the Yield of Irrigated Lucerne at Griffith, N.S.W.

*By E. S. West, M.S.**

Summary.

The growth of lucerne on the Murrumbidgee Irrigation Areas was found to be almost entirely dependent on dressings of phosphatic fertilizers. Dressings of up to 4 cwt. per acre gave increased yields; but the data suggests that 6 to 8 cwt. dressings would give still larger yields.

The effect of an initial dressing of 1 ton of rock phosphate was still evident after seven years.

In 1926, a phosphatic fertilizer experiment with irrigated lucerne was commenced at the Commonwealth Research Station, Griffith. The following treatments were applied:—

No fertilizer applied.
1 cwt. superphosphate per acre per annum.
2 cwt. superphosphate per acre per annum.
4 cwt. superphosphate per acre per annum.
1 ton rock phosphate per acre (initial dressing only).

The superphosphate contained 22 per cent. P_2O_5 most of which is water soluble. The rock phosphate was finely ground and contained 37 per cent. P_2O_5. The rock phosphate was ploughed under before the lucerne was sown.

The experiment ran for seven years, when it was considered that it had yielded all the data desired, and was discontinued.

Yield.

Table 1 shows the yields obtained, and the results are shown graphically in Fig. 1.

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TABLE 1.—SHOWING THE YIELDS OF LUCERNE (IN TONS PER ACRE) OBTAINED WITH VARIOUS DRESSINGS OF FERTILIZERS.

Years.	0.	1 Cwt. Super-phosphate.	2 Cwt. Super-phosphate.	4 Cwt. Super-phosphate.	1 Ton† Rock Phosphate.	Significant Difference.
1926–27	2·35	4·46	4·98	4·93	2·91	0·85
1927–28	1·25	3·45	5·30	6·00	3·54	0·85
1928–29	0·88	2·60	5·12	7·57	4·02	1·07
1929–30	0·64	2·13	4·47	6·93	3·80	0·58
1930–31	1·12	3·00	4·66	6·24	3·86	0·49
1931–32	0·77	2·11	3·96	5·15	3·32	0·49
1932–33	0·47	1·68	3·49	5·82	2·41	1·29
Total seven years ..	7·48	19·43	31·98	42·64	23·86	..

† Initial dressing only.

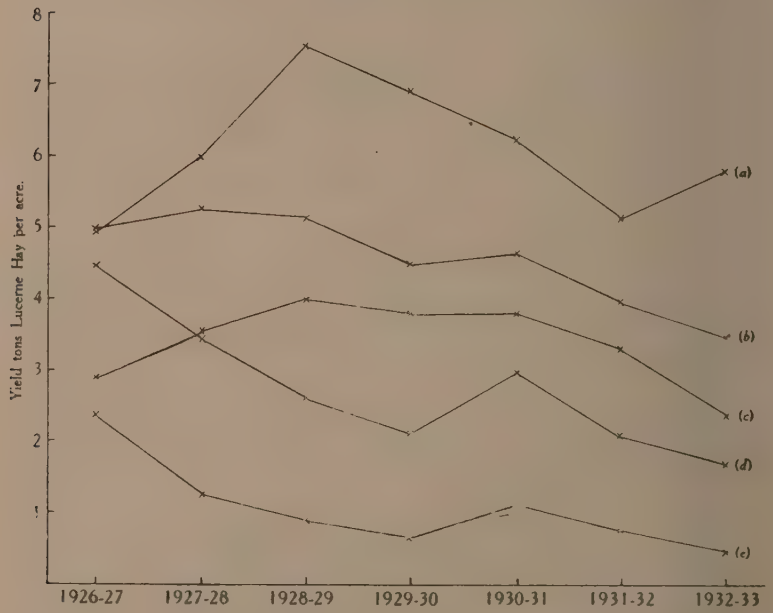

FIG. 1.—(*a*) 4 cwt. super. (*b*) 2 cwt. super. (*c*) 1 ton Rock Phosphate. (*d*) 1 cwt. super. (*e*) No fertilizer.

There were four replications of the untreated and 2-cwt. dressings, but only three of the other treatments.

Unfortunately, the various treatments were not randomized so that a rigid statistical analysis is not possible; but the results are so definite that they leave no doubt of the relative merits of the different treatments.*

* The writer is indebted to Miss F. E. Allan, M.A., Biometrician of the Division of Plant Industry, for the statistical analysis.

The experiment shows the absolute dependence of lucerne in this district on phosphatic fertilizers. Without superphosphate, practically no lucerne was produced. Even one hundredweight of superphosphate was insufficient to maintain a reasonable stand.

Fig. 2 shows the relationship between the total yield obtained and the superphosphate applied. The curve is a Mitscherlich curve. This has been drawn, not with the idea that this is justified from the data, but just to show in a general way what might be expected from heavier dressings. It is to be seen that in all probability an 8-cwt. dressing would have given still greater yields.

When this experiment was laid down, a 4-cwt. dressing was considered a very heavy dressing, and the maximum possible yield was expected from it. From experience under irrigation conditions, we must regard 4 cwt. as a rather light dressing, and 6 to 8 cwt. should be regarded as a suitable dressing where phosphates are required.

The effect of the rock phosphate is interesting. At first, it had comparatively little effect on the yield, but by the third year and until the end of the experiment, the rock phosphate plots yielded better than the 1-cwt. super. plots; but not as well as the 2-cwt. plots. This suggests the economic possibility of ploughing-in heavy initial dressings of rock phosphate to be supplemented by annual dressings of superphosphate. Whether this would be worth while, of course, would depend on the relative local prices of the rock phosphate and superphosphate.

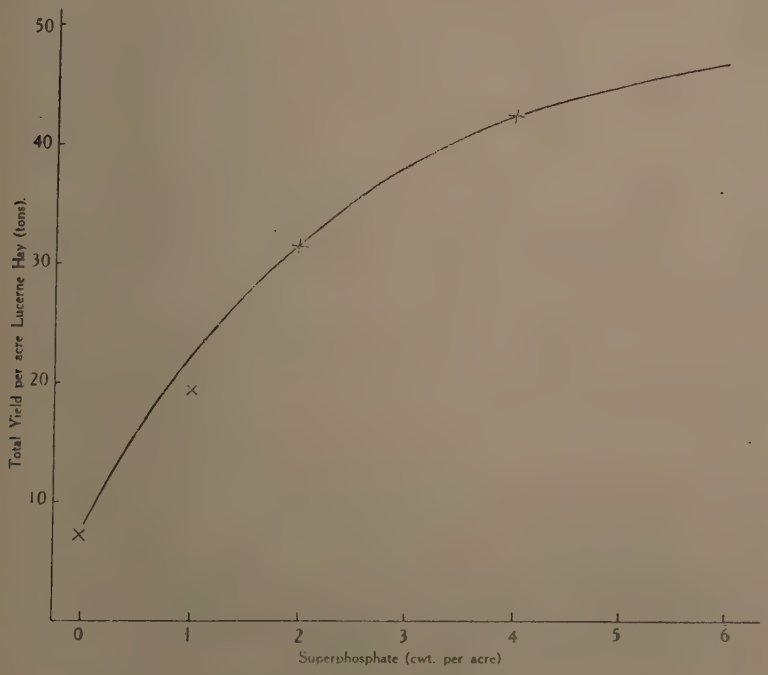

Fig. 2.

Zinc-cured Mottle Leaf in Citrus Induced by Excess Phosphate.

*By E. S. West, M.S.**

Summary.

Foliocellosis, or zinc-cured mottle leaf of citrus trees, occurs on the superphosphate plots of the fertilizer field at the Commonwealth Research Station, Griffith, New South Wales, apparently being induced by the phosphate ion. Potash appears to slightly increase the incidence of foliocellosis when phosphates are also present. The mottling is reduced by a zinc sulphate spray.

1. Introduction.

In 1924, a field was planted with citrus trees for a permanent fertilizer experiment at the Commonwealth Research Station, Griffith. Plots receive nitrogen as ammonium sulphate, potash as potassium sulphate, and phosphate as superphosphate, in all combinations with or without each ingredient, making eight treatments which are replicated four times. The field is planted with alternate rows of Valencia Late and Washington Navel Oranges, and each plot consists of eight trees, viz., two alternate rows of Navels and two of Valencias each of two trees. Each plot is separated from the adjoining plots by a single row of guard trees.

In the spring of 1930, it was noted that trees receiving superphosphate developed mottle leaf. This mottle leaf was typical of the well-known, zinc-cured, mottled leaf or foliocellosis, the symptoms of which are small leaves and typical yellow areas between the veins. The mottle leaf on the phosphate plots has persisted since that time. Practically every test tree on the phosphate plots and the guard trees of the phosphate plots showed the symptoms; while the symptoms were almost entirely absent from any other trees.

Tree injection tests failed to produce any results on mottled twigs with any of the following salts:—Zinc sulphate, manganese sulphate, magnesium sulphate, ferrous sulphate, or ferric citrate; neither could mottling be induced by injecting sodium phosphate (Na_2HPO_4) into healthy twigs.

Even fairly large twigs of citrus have a small diameter, and the injection was not very simple mechanically so that possibly it was ineffective. The iron caused gumming, so that some of the salt was evidently absorbed into the conducting tissue.

In the spring of 1936, every alternate row (across the rows of Navels and Valencias) was sprayed with zinc sulphate. In this way each plot had one row sprayed and one row not sprayed, and had two Valencias and two Navels sprayed and two Valencias and two Navels not sprayed.

* Officer in charge, Commonwealth Research Station, Griffith.

In the spring of 1937, the trees were examined for foliocellosis, and the results were subjected to a statistical analysis* with the following results:—

Effect of Fertilizer.

Numbers of diseased trees. Totals of 32 sub-plots (64 trees).

With phosphate and potash	52
With phosphate and no potash	35
With phosphate and nitrogen	46
With phosphate and no nitrogen	41
Washington Navels	41
Valencia Lates	46
Sprayed with zinc sulphate	38
Unsprayed	49

Numbers of diseased trees. Totals of 64 sub-plots (128 trees).

With phosphate	87
Without phosphate	0

The effect of the phosphate is, of course, definite. When phosphate is present, potash slightly increases the foliocellosis (probability= approximately .05).

The effect of the variety and spraying is not statistically significant in this analysis.

2. Effects of Spraying.

The effect of spraying was also compared by the Chi-squared test. This permitted the use of the horizontal guard rows adjoining phosphate plots, which is legitimate for the comparison.

When this is done, it is found that, out of a total of 362 trees that received phosphate, half of which were sprayed and half unsprayed, 39 per cent. of the unsprayed trees had foliocellosis, while only 26 per cent. of the sprayed trees showed the symptoms. The spraying has significantly reduced the symptoms (P just over the .01 level).

3. Discussion.

Superphosphate conveys the sulphate ion to the soil as well as phosphate; but, as large amounts of sulphate are carried by ammonium sulphate also, the possibility of sulphates being responsible for the mottle leaf is contra-indicated. One must ascribe the effect either to calcium phosphate or the acid nature of the superphosphate. As the B2 horizon of this soil—which includes a large part of the root zone—contains considerable limestone, it is unlikely that the calcium is the cause. Neither is it very likely that the cause is the acidity of the

* The writer is indebted to Miss F. E. Allan, M.A., Biometrician of the Division of Plant Industry, for the statistical analysis.

superphosphate, though, of course, this is a possibility. At present, one is fairly safe in ascribing the cause to the excess of the phosphate ion. It may be mentioned that 12¼ lb. of superphosphate (22 per cent. P_2O_5) per tree is applied, concentrated in four furrows between the trees. As the trees are 22 feet apart, the concentration in the furrow is approximately 9 lb. per linear chain.

Zinc-cured mottle leaf of citrus is now generally regarded as zinc deficiency. Apparently, therefore, we have here a case of phosphate induced zinc deficiency.

Zinc phosphate is very insoluble; but it is unlikely that the phosphate has rendered unavailable to the plant all the zinc in the soil, as the phosphate is applied to a very limited portion of the soil. A possible explanation is that the excess absorption of phosphate causes the precipitation of the zinc absorbed by the plant. Olsen* has shown that excess absorption of the phosphate ion causes the precipitation of iron within the plant tissue, leading to chlorosis. In this case the iron accumulates near the veins of the leaves, but does not get into the mesophyll and pallisade tissue. Olsen found the affected trees contained higher amounts of P, Ca, Mg, K, and N. The similarity to the composition of mottled citrus leaves reported by Kelley and Cummins† who found greater amounts of P, Mg, K, N, and S, but less Ca in the mottled than normal leaves is to be noted.

It may be mentioned that severe foliocellosis is not very common on the Murrumbidgee Irrigation Areas; though a few cases of severe trouble have occurred on old trees. The phosphate induced foliocellosis on the fertilizer plots, generally speaking, is not severe, although a few trees are badly affected. Other cases of foliocellosis induced by superphosphate have been reported to the writer. Ordinarily speaking, it is not expected that any great danger occurs in using superphosphate on citrus groves. The trees here reported had heavy concentrations of superphosphate applied to the soil, and the foliocellosis induced was not alarming. It is unlikely that the superphosphate ordinarily used in growing green crops, where they are grown for green manure, would prove harmful. However, one might be guarded against using heavy dressings of superphosphates for citrus where foliocellosis is common. Ordinarily speaking, as citrus trees do not respond to phosphates, except indirectly by increasing the growth of green manure, no particular problem is presented.

* Olsen, C., 1936. *Compt. Rend. Lab. Carlsberg. Chem. Ser.* 21: No. 3. p. 1-52.
† Kelley, W. P., and Cummins, A. B., 1920. *J. Agric. Res.* 20: 161-191.

The Permanganate Number and Its Application in Determining the Degree of Cooking of Eucalypt Sulphate Pulps.

By P. B. Edwards, B.Sc., and A. W. Mackney, M.Sc.†*

Summary.

The main variables in the determination of the permanganate number of eucalypt sulphate pulps by the Oestrand method have been investigated. Alterations in the method have been made to accommodate pulps with a permanganate consumption above a certain figure, and the value obtained by the amended method has been designated the "true" permanganate number. Experimental tolerances for the main variables have been determined.

The relationships of "true" permanganate number to chlorine number, lignin, and solubility in sodium hydroxide have been investigated, and the results are stated mathematically. Similarly, the relationships of chlorine number to lignin and solubility in sodium hydroxide have been determined. It is concluded that the permanganate number determination gives a useful indication of the degree of cooking of a pulp but is not adequate to measure the total non-carbohydrate fraction of the pulp except within relatively wide limits.

Introduction.

It has been recognized for a number of years (1, 2) that it is desirable, for the scientific control of pulping operations, to determine the degree of cooking of a pulp while cooking is in progress. The determination must be of such a nature that it can be carried out rapidly and the results applied before over-cooking occurs. Since it is possible to take a pulp sample from the digester (3), a number of rapid methods for determining degree of cooking has been evolved, and in some mills it is now the custom to cook to a definite chemical standard.

To estimate degree of cooking, the lignin content must be determined and, since direct determination is a lengthy procedure, one of a number of indirect methods must be applied. The basis of these methods is the oxidation or chlorination of the non-carbohydrate constituents of the pulp under clearly defined conditions. The three reagents commonly employed are (*a*) potassium permanganate, (*b*) chlorine (either gaseous or aqueous), and (*c*) bleaching powder. Of these the last (*c*) is unsatisfactory for rapid work, since the standard procedure of the United States Forest Products Laboratory (4) requires the wet equivalent of 30 grams of oven-dry pulp and several different bleach ratios. Nevertheless, this method, which is actually a combination of chlorination and oxidation, is valuable for determining the bleachability of a pulp and is probably the only direct method of measuring this quantity which allows at the same time determination of the colour of the bleached pulp.

Methods (*b*) (2, 5) involving the use of either gaseous or aqueous chlorine, which give a rapid measure of the degree of cooking of the pulp by means of the relatively simple formation of the chloro-lignin, have been evolved. However, these involve on the one hand the use of a bulky and rather delicate apparatus of the gas analysis type, and on the other the application of a special type of trap to absorb chlorine

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evolved from the nearly saturated chlorine water. Consequently, the determination is not easily adapted to routine mill work. Further, chlorine, either in the gaseous or aqueous state is unstable, and difficult to handle.

The use of potassium permanganate to determine degree of cooking was apparently first reported in 1923 (1), and since that time a number of modifications to the method have been made. However, the basic principle, which involves the oxidation of non-carbohydrate constituents of the pulp, remains unaltered. Since the method is rapidly carried out, requiring only 5 minutes for the oxidation and approximately 20 minutes for the complete determination, and further, since the chemicals required are relatively stable and easily handled, it has been chosen as the logical first line of inquiry in an investigation dealing with eucalypt sulphate pulps.

In utilizing this method for determining degree of cooking, it has been necessary at the same time to consider a wider application of the results. The permanganate number (i.e. permanganate consumed under specified conditions) will be shown to bear a definite relationship to the extractives and lignin content of the pulp, and for this reason alone, considering the rapidity of the determination, it is of value. An extremely useful indication of the lignin content of a pulp may be obtained rapidly by the method, although it is unlikely that the permanganate number will suffice to replace the lignin value.

A further process which is of the utmost importance to mill control is the determination of pulp bleachability. Although the chemical processes of the permanganate number determination are different from those of a calcium hypochlorite bleach (the latter involves chlorination as well as oxidation) attempts (1, 2, 6, 7, 8) have been made to relate permanganate number to bleachability. To a certain degree, success has been achieved, although the factor is variable, depending on the lignin content of the pulp. In addition, Johansson (8) has shown that a straight line relationship exists between permanganate number and chlorine number, and Bergman (9) has attempted to relate chlorine number to bleachability.

It can be seen clearly from the above that there is some possibility of utilizing permanganate number to express both degree of cooking and bleachability of a pulp. In the present investigation, however, consideration of the latter portion of the problem has been deferred, and attention has been given to adapting the Oestrand permanganate number (8) to eucalypt sulphate pulps. This portion of the work is discussed in Part A and is followed by an investigation (Part B) of the relationship of the "true" permanganate number* to chlorine number, lignin, and sodium hydroxide extractives.

Part A.—Investigation of Variables in the Oestrand Permanganate Number Determination.

Material.—The investigation was carried out on a number of pulps prepared by sulphate cooking from *E. sieberiana*. The pulps used in evaluating the different variables were selected as representative of either well-cooked or raw samples.

* Throughout this article the term "true permanganate number" is used for want of a better term to indicate the difference between the two values. There is no special significance in the use of the word "true."

Method.—After consideration of the methods available, the procedure for determination of permanganate number as set out by Oestrand (8) was adopted for further investigation. An arbitrary alteration in temperature from 20° to 25°C. was made on account of climatic conditions. The method studied is as follows:—

Air-dry, disintegrated pulp, corresponding to one gram of oven-dry pulp, is weighed into a 600 ml. tall type Pyrex beaker and 180 ml. distilled water and 20 ml. sulphuric acid (1 vol. conc. acid, sp. gr. 1.84, to 9 vols., water) added. The mixture is stirred slowly by means of a glass stirrer until wet and then at a regular speed of 500 r.p.m. The temperature is adjusted to 25°C. and 50 ml. 0.1 N potassium permanganate at the same temperature are added from a beaker; stirring is continued for exactly five minutes when the reaction is stopped by the addition of 50 ml. 0.1 N ferrous ammonium sulphate solution containing 100 ml. of conc. sulphuric acid per litre. When the solution is quite colourless, the clear solution is back titrated with 0.1 N potassium permanganate until the first pink colour appears. It is convenient for the back titration to leave the beaker *in situ* and continue the stirring. The permanganate number is expressed as the number of millilitres of 0.1 N potassium permanganate consumed per gram of oven-dry pulp.

Experimental Procedure.—The reactions were carried out in a lagged copper water bath (16 inches x 8 inches x 5 inches deep) maintained at a constant temperature by means of a small carbon filament lamp thermostatically controlled. The water in the bath was kept circulating by means of a small electric stirrer fitted with a metal propellor revolving at approx. 400 r.p.m. The solutions used in the determination were kept at a constant temperature in the water bath in three glass stoppered 500 ml. Erlemeyer flasks. Distilled water was kept in two similar flasks, one being fitted as a wash-bottle and the other used as a reserve supply. The solutions in the reaction beaker were stirred by means of a small electric variable speed stirrer fitted with a glass propeller.

In order to determine the flexibility and adaptability of the method, each of the major variables was investigated in turn, the remaining variables being kept constant at the values outlined in the above method. All determinations were carried out in duplicate.

(*a*) Temperature: One well-cooked pulp (J10) was investigated at temperatures ranging from 20° to 30°C. The results are represented diagrammatically in Fig. 1.

(*b*) Rate of Stir: Two pulps, one well-cooked (J10) and one fairly raw (J16), were investigated over a range of three speeds of the stirrer. The results are given in Table 1.

Table 1.

Rate of Stir in r.p.m. (approximate).	—	180.	300.	500.
Ml. 0·1 N, $KMnO_4$ per gm. of O.D. pulp ..	J10	12·3	12·2	12·2
	J16	31·3	31·0	31·0

(*c*) Time: Two well-cooked pulps (J17, J18) and one fairly raw pulp (J16) were examined at reaction times ranging from 0.5 min. to 15 minutes. The results are represented diagrammatically in Fig. 2.

(*d*) Rate of Titration: On account of fading end-points experienced in the back titration with 0.1 N potassium permanganate, the determinations given in Table 2 were carried out to evaluate the effect of rate of titration.

TABLE 2.

Rate of Titration.	—	4·5 ml./min.	35 ml./min.
Ml. 0·1 N, $KMnO_4$ per gram of O.D. pulp ..	J10	12·3	12·2
	J16	31·1	31·0

(*e*) Weight of Pulp: Two well-cooked pulps (J13, J18), and one raw pulp (J14) were examined. The results have been expressed as millilitres of 0.1 N potassium permanganate consumed by the weight of pulp taken and are represented diagrammatically in Fig. 3

(*f*) Volume of Permanganate Added: One raw pulp (J14) was examined using quantities of permanganate ranging from 50 to 150 ml. on one gram of pulp. The results are represented diagrammatically in Fig. 4.

Discussion.

(*a*) *Temperature.*—As already indicated, an arbitrary change was made in the reaction temperature of the Oestrand method in order to avoid cooling the reaction bath on days when room temperatures were above 20°C. The results plotted in Fig. 1 show a straight line relationship between temperature and permanganate number over the range 20° to 30°C. Consequently, within these limits, any controlled temperature is satisfactory, the variation in permanganate number being 0.13 units per °C. An allowable variation of ± 0.5°C. has been fixed upon to provide a reasonable practical working margin.

(*b*) *Rate of Stir.*—The results set out in Table 1 indicate that, even with the slowest practical rate of stirring (180 revs/min)), sufficient agitation of the reaction mixture is obtained to permit oxidation to follow a normal course. With one well-cooked and one relatively raw pulp, no variation in permanganate number was detected over the full range at which the stirrer was used. For practical purposes the remainder of this work was carried out at a stirring rate of approx. 350 revs. per minute, this being the maximum rate to give smooth stirring and at the same time avoid splashing up the sides of the beaker.

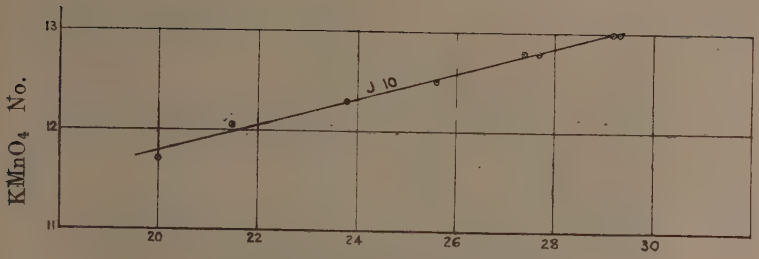

$KMnO_4$ No.
13
12
11
J 10
20
22
24
26
28
30
Temperature in Degrees Centigrade.

FIG. 1.

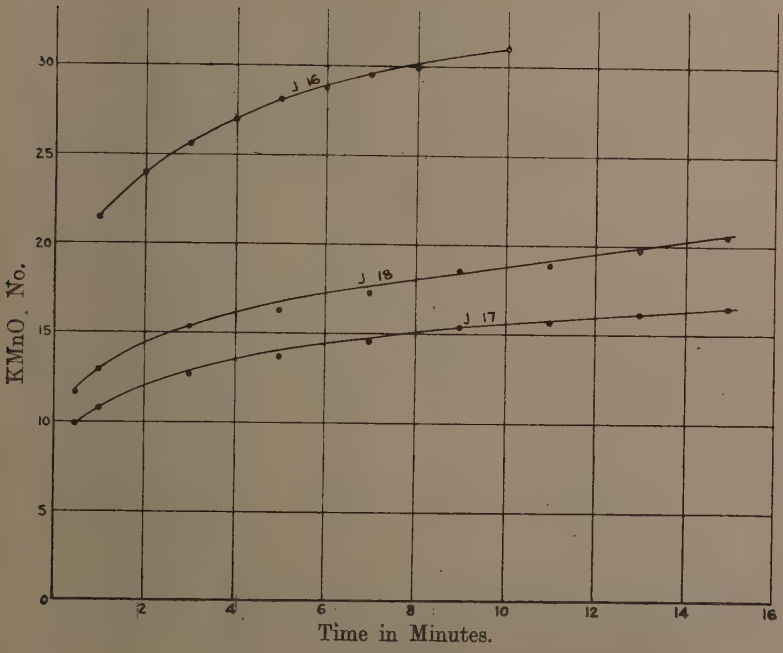

KMnO. No.
30
25
20
15
10
5
0
J 16
J 18
J 17
2
4
6
8
10
12
14
16
Time in Minutes.

FIG. 2.

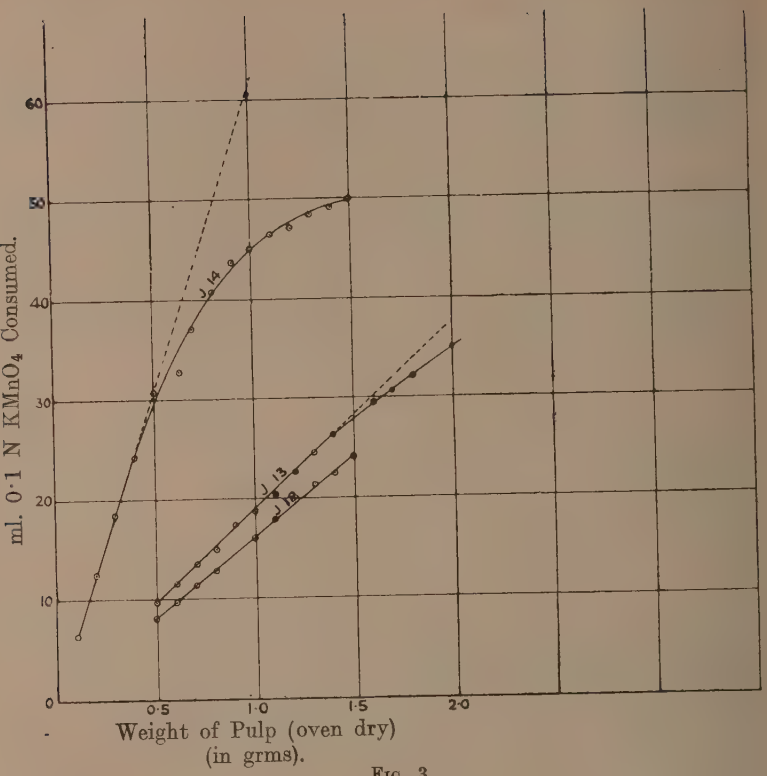

ml. 0·1 N $KMnO_4$ Consumed.
60
50
40
30
20
10
0
J 14
J 13
J 15
0·5
1·0
1·5
2·0
Weight of Pulp (oven dry)
(in grms).

Fig. 3.

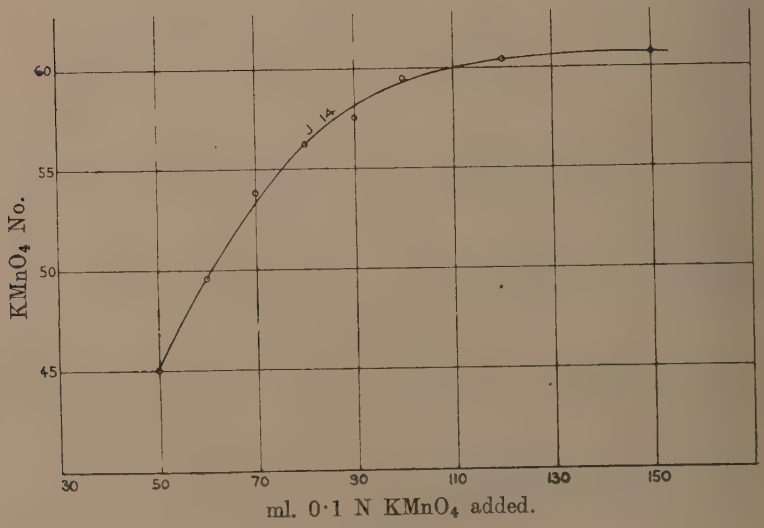

$KMnO_4$ No.
60
55
50
45
J 14
30
50
70
90
110
130
150
ml. 0·1 N $KMnO_4$ added.

Fig. 4.

(*c*) *Time.*—Since oxidation by means of potassium permanganate is not restricted to lignin and extractives only but may affect water soluble carbohydrate constituents, it is to be expected that the reaction will proceed rapidly in the early stages and will gradually slacken. The results set out in Fig. 2 indicate that the major part of the oxidation is complete within two minutes, but that it is still proceeding slowly, even after five minutes. The well-cooked pulps (J17, J18), during the first five mintues of reaction time, show an average increase in permanganate number of approx. three units per minute, and this rate decreases to an average of 0.4 units per minute during the second five minutes of the reaction. Similarly, the raw pulp (J16) shows a drop in the average rate of increase of permanganate number from 5.6 to 0.6 units per minute from the first to the second five minutes of the reaction. These increments during the second five minutes of the reaction are sufficiently small to allow the assumption that, for practical purposes, the reaction is complete within five minutes. It should also be pointed out that in the case of the raw pulp the larger increments in permanganate number after five minutes are consistent with the presence of a greater amount of oxidisable material and with the fact that, at the end of two minutes reaction time, insufficient excess of permanganate remains to allow the reaction velocity to proceed at the normal rate (cf. section (*e*) below.).

(*d*) *Rate of Titration.*—Since the Oestrand method specifies titration to an end-point indicated by the appearance of the first pink colour, and since in addition this colour tends to fade through further oxidation of the pulp, it seemed probable that a slow titration would yield high back-titration values with low permanganate numbers. However, the results shown in Table 2 indicate that the total permanganate absorbed is independent of the rate of back titration. It would appear rather that a selective reaction of the permanganate with the ferrous salt takes place before any further pulp oxidation occurs.

(*e*) *Weight of Pulp and Excess of Permanganate.*—(The results shown in Figs. 3 and 4 may conveniently be discussed together).—In determining the effect of the ratio of permanganate used to weight of pulp, it is immediately apparent that an important relationship exists, and unless a definite excess of permanganate is present the reaction velocity decreases and low permanganate numbers are obtained. In Fig. 3 the volume of 0.1 N permanganate consumed is plotted against weight of pulp for two well-cooked pulps (J18, J13) and one very raw pulp (J14). In the case of pulp J18 a straight-line relationship holds over the range studied (0.5 gm.-1.5 gm.), the maximum volume of permanganate consumed being 24 ml. However, over the wider range studied for pulp J13 (0.5 gm.-2.0 gm.), a distinct decrease is observed in permanganate number with the larger amounts of pulp, and a similar, but very much more marked, effect is obtained for pulp J14. In each case a straight-line relationship holds up to the same point (viz. : a consumption of approx. 25 ml. permanganate) and thereafter a more or less marked decrease occurs. It is clear from these results that a definite excess of permanganate must be maintained throughout the reaction.

In Fig. 4 the permanganate number of pulp J14 is plotted against the number of millilitres of permanganate added, and it is shown that, provided a sufficient excess of permanganate is added, a maximum value is reached which corresponds to that obtained by the Oestrand method when the permanganate consumption is below 25 ml. (using 0.4 gm. or less of pulp). Further, the maximum value obtained from Fig. 4 for 1 gram of pulp is found to lie on the extension of the straight line for pulp J14 shown in Fig. 3.

It is apparent, then, that for any weight of pulp it is possible to derive a constant permanganate number provided that the ratio of the number of millilitres of permanganate added, to the number of millilitres of permanganate consumed, is not less than 50:25. In order to provide a safe working margin this ratio has been increased to 50:20. Such a relationship may be achieved by (i) increasing the volume of permanganate used beyond the 50 ml. stipulated in the Oestrand method (ii) decreasing the weight of pulp taken for the determination. Since for a raw pulp the weight required to give a 5:2 ratio may be less than 0.4 gm., the second alternative must be rejected on account of probable weighing and sampling errors. Consequently, in carrying out the Oestrand determination using one gram of pulp, in all cases in which the permanganate consumption has been found to exceed 20 ml. check determinations using a greater excess of permanganate have been carried out. Further, when it has been necessary to use amounts of permanganate greater than 50 ml. the quantities of sulphuric acid and water have been increased in the same proportion in order to keep the concentration of permanganate constant.

Summary.

In determining the permanganate number of pulps by the Oestrand method the procedure as set out (p. 187) has been found satisfactory except in those cases in which the permanganate consumption exceeds 20 mls. In such cases, the method has been altered to provide that the ratio permanganate added to permanganate consumed shall be 5: 2 or greater. The ratio permanganate: sulphuric acid: water must remain at the value 5:2:18 as set out in the Oestrand method. In addition it has been found convenient to reduce the rate of stirring during the reaction from 500 revs. per min. to approx. 350 revs. per min. in order to avoid splashing.

Tolerances to be allowed in the remaining variables are as follows:—

Temperature	25°	±	0.5°C.
Time of reaction	5 min.	±	15 secs.

The method with these modifications has for the purpose of the remainder of this work been designated "true" permanganate number. In general the Oestrand number and true number will be the same for values below 25.

Part B.—Relationship of Permanganate Number to Chlorine Number, Lignin, and Solubility in Sodium Hydroxide.

Material.—The investigation was carried out on a series of 55 pulps prepared by means of sulphate cooking using total alkali ranging from 15 per cent. to 27 per cent. The pulps were from three species, viz.: *E. sieberiana* (25), *E. regnans* (27), and *E. obliqua* (3). Methods:—The determinations carried out on each pulp were (*a*) permanganate number, (*b*) solubility in hot 0.5 per cent. sodium hydroxide, (*c*) lignin, (*d*) chlorine number (on *E. sieberiana* pulps only).

(*a*) The permanganate number as outlined on p. 187, with the modifications summarized on p. 192, was used throughout the work. In the case of a consumption of permanganate exceeding 20 ml. per gram of pulp, both the Oestrand and true permanganate numbers have been determined.

(*b*) The solubility in sodium hydroxide was determined as the loss in weight of the pulp sample after extraction with boiling 0.5 per cent. sodium hydroxide solution for one hour.

(*c*) The lignin determination was carried out according to the modified United States Forest Products Laboratory method (10), with the exception that the pulp was extracted beforehand with hot 0.5 sodium hydroxide for one hour and was then thoroughly teased out before treatment with 72 per cent. sulphuric acid.

(*d*) Chlorine number was determined as the weight of chlorine absorbed by 100 grams of oven-dry pulp from a freshly prepared solution of chlorine water (approx. 0.6 per cent.). The method used (5, 11) is as follows:—

The air-dry equivalent of 1.5 grams ($\pm$ 0.01 gm.) of oven-dry pulp is weighed into a 250 ml. filtering flask and then steamed until there is an increase in weight of 5 grams. The flask is then cooled to 20°C. The side-arm of the flask is fitted with a three-bulb gas bubbler containing 10 ml. 30 per cent. potassium iodide solution, and the flask is fitted with a rubber stopper carrying a glass tube drawn out to a jet. Then 100 ml. of freshly prepared chlorine water (approx. 0.6 per cent.) at 20°C. are added from a constant feed burette connected to the glass jet inlet by means of a rubber tube. The flask is closed with a screw clip and shaken for 15 minutes. The potassium iodide from the bubbler, together with a further 10 ml. of 30 per cent. solution, is then run into the flask by tilting, and the liberated iodine is titrated with 0.5 N sodium thiosulphate using starch as an indicator. A control titration of the chlorine water is made at the same time.

The pulp sample should be carefully shredded before weighing in order to facilitate wetting. Steaming is applied for the same purpose. Throughout the determinations the chlorine water is stored in a black bottle in a deep water bath at a temperature of 20°C. ($\pm$ 0.5°C.). The glass jet leading into the reaction flask is filled with chlorine water before connecting to the flask and remains full throughout the determination, acting merely as an extension to the burette.

Results.—The results of the above four determinations are set out in Table 3.

TABLE 3.

Species.	Pulp.	Oestrand Permanganate Number.	True Permanganate Number.	Solubility in 0·5 per cent. Sodium Hydroxide.	Lignin.	Sum of Lignin and Caustic Soluble.	Chlorine Number.
E. sieberiana	J3 ..	40·6	49·8	4·2	4·1	8·3	9·4
,, ..	J4 ..	39·7	48·7	5·4	3·7	9·1	8·1
,, ..	J5 ..	40·0	50·1	5·6	3·8	9·4	9·1
,, ..	J6 ..	40·2	50·8	5·8	4·3	10·1	9·3
,, ..	J7 ..	40·5	49·6	..	..	..	9·2
,, ..	J8 ..	25·8	27·4	3·5	2·2	5·7	6·7
,, ..	J9 ..	16·0	16·0	2·7	1·5	4·2	4·4
,, ..	J10 ..	12·3	12·3	3·2	1·0	4·2	3·3
,, ..	J12 ..	37·6	42·8	..	..	..	8·1
,, ..	J13 ..	19·0	19·0	3·3	1·4	4·7	4·1
,, ..	J14 ..	45·1	60·3	7·2	3·1	10·3	10·8
,, ..	J16 ..	31·1	34·9	3·3	2·8	6·1	8·1
,, ..	J17 ..	14·2	14·2	2·5	0·4	2·9	3·4
,, ..	J18 ..	16·2	16·2	1·9	1·0	2·9	4·0
,, ..	J19 ..	12·8	12·8	2·0	0·5	2·5	4·1
,, ..	J20 ..	16·8	16·8	2·7	0·6	3·3	3·9
,, ..	J21 ..	13·4	13·4	2·3	0·6	2·9	2·7
,, ..	J22 ..	35·7	41·7	5·2	2·7	7·9	8·9
,, ..	J23 ..	15·7	15·7	2·5	1·2	3·7	3·9
,, ..	J25 ..	15·7	15·7	2·5	1·1	3·6	3·2
,, ..	J27 ..	15·4	15·4	2·4	0·7	3·1	4·5
,, ..	J28 ..	40·6	51·1	4·4	3·5	7·9	9·6
,, ..	J29 ..	20·1	20·1	2·8	1·1	3·9	3·8
,, ..	J30 ..	12·3	12·3	2·3	0·4	2·7	3·8
,, ..	J31 ..	11·6	11·6	2·2	0·2	2·4	3·0
,, ..	PC4A	36·9	43·9	5·2	3·6	8·8	..
E. regnans ..	PC4B	18·1	18·1	3·0	0·7	3·7	..
,, ..	PC4C	15·9	15·9	2·7	0·4	3·1	..
,, ..	PC4D	14·9	14·9	2·5	0·4	2·9	..
,, ..	PC5A	21·6	21·6	2·9	1·7	4·6	..
,, ..	PC5B	13·8	13·8	2·2	0·3	2·5	..
,, ..	PC5C	12·7	12·7	2·1	0·2	2·3	..
,, ..	PC5D	10·8	10·8	1·9	0·3	2·2	..
,, ..	PC6A	21·0	21·0	2·9	1·8	4·7	..
,, ..	PC6B	13·5	13·5	2·4	0·4	2·8	..
,, ..	PC6C	11·9	11·9	2·1	0·4	2·5	..
,, ..	PC6D	10·8	10·8	1·7	0·4	2·1	..
,, ..	PC7A	15·3	15·3	2·1	0·6	2·7	..
,, ..	PC7B	13·1	13·1	2·1	0·4	2·5	..
,, ..	PC7C	11·0	11·0	1·7	0·2	1·9	..
,, ..	PC7D	10·6	10·6	1·7	0·2	1·9	..
,, ..	PC8A	18·9	18·9	2·4	1·2	3·6	..
,, ..	PC8B	13·4	13·4	2·2	0·5	2·7	..
,, ..	PC8C	12·4	12·4	2·1	0·3	2·4	..
,, ..	PC8D	10·4	10·4	2·0	0·3	2·3	..
,, ..	PC9A	39·6	50·5	6·2	4·1	10·3	..
,, ..	PC9B	19·4	19·4	2·9	1·3	4·2	..
,, ..	PC9C	16·3	16·3	2·6	0·4	3·0	..
,, ..	PC9D	13·3	13·3	2·3	0·3	2·6	..
E. obliqua ..	PC10A	25·8	25·9	2·9	2·0	4·9	..
E. regnans ..	PC11A	16·1	16·1	2·8	0·7	3·5	..
E. obliqua ..	PC12A	20·7	20·7	2·2	1·4	3·6	..
E. regnans ..	PC17A	17·1	17·1	2·3	0·9	3·2	..
E. obliqua ..	PC19A	28·3	30·4	3·0	2·3	5·3	..
E. regnans ..	PC20A	21·9	21·9	3·0	2·2	5·2	..

Discussion.

(*a*) *Order of Accuracy of Results.*—An indication of the order of accuracy of each of the determinations was obtained by taking half of the arithmetic mean of the difference between individual results. In all cases duplicate determinations were carried out. The figures are given in Table 4.

TABLE 4.

Determination.	Order of Accuracy.
Permanganate Number (both methods)	± 0·1
Solubility in 0·5 per cent. sodium hydroxide	± 0·2
Lignin	± 0·1
Chlorine Number	± 0·25

It should be pointed out that the order of accuracy figure for chlorine number is obtained from only 20 out of the total number of 25 determinations. On the remaining five determinations a much larger number of replications (4-8) was made, and on these the variation between minimum and maximum values ranged from ± 0.6 to ±1.4.

(*b*) *Relationship of Oestrand Number to True Permanganate Number.*—In order to economize in the time required for the determination of permanganate number and to avoid repetition in cases which are beyond the satisfactory limit for the Oestrand method, a curve has been drawn (Fig. 5) to relate Oestrand number to true number. This will, in general, provide a satisfactory indication of the latter from the former for values between 20 and 40 and will be useful in mill control work. For values above 40, as the Oestrand number tends to its maximum of 50 and the slope of the curve rapidly diminishes, the error will be too great to allow a valid relationship.

(*c*) *Relationship of True Permanganate Number and Chlorine Number to Other Variables.*—In the discussion of these relationships the results have been treated statistically to obtain the regression of the dependent variable on the independent variable and the standard error of the estimate (12). In each case the regression line has been plotted (Figs. 6, 7, 8), and the limits within which 95 per cent. of the points fall are shown by dotted lines. Table 5 shows the relationships established from the figures available.

The following conclusions may be drawn:—

(i) Although only 25 chlorine number figures have been reported, it is clear that, from the point of view of accuracy and ease of manipulation, this determination (as carried out in this work) is not satisfactory either for research purposes or for mill control work. It is probable

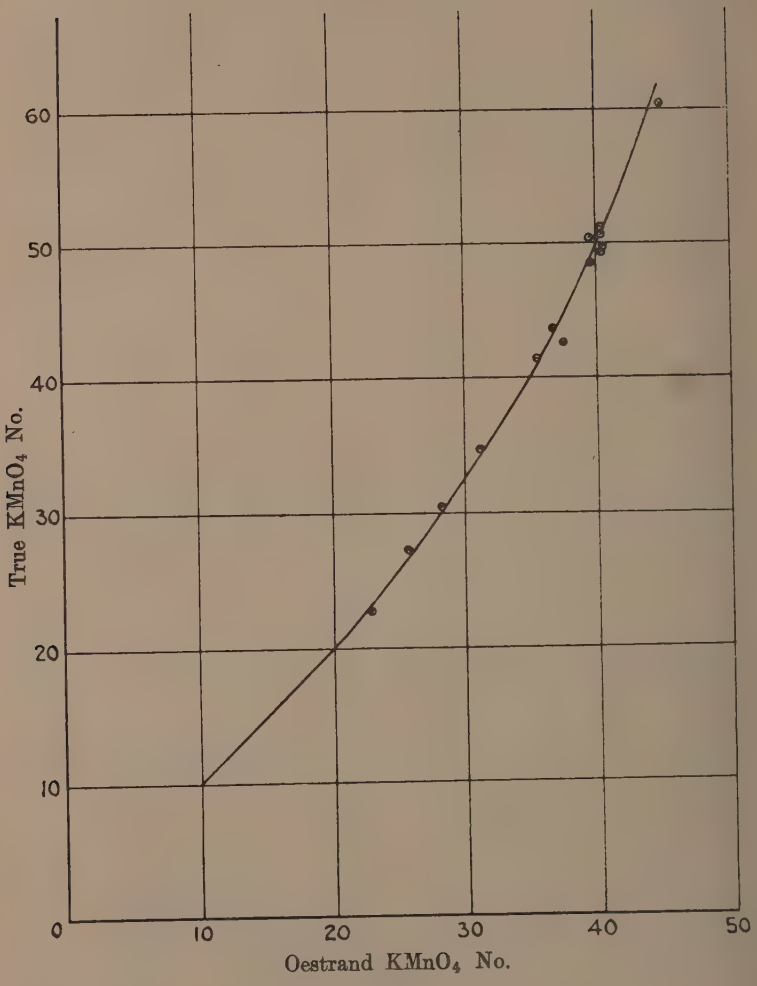


Fig. 5.

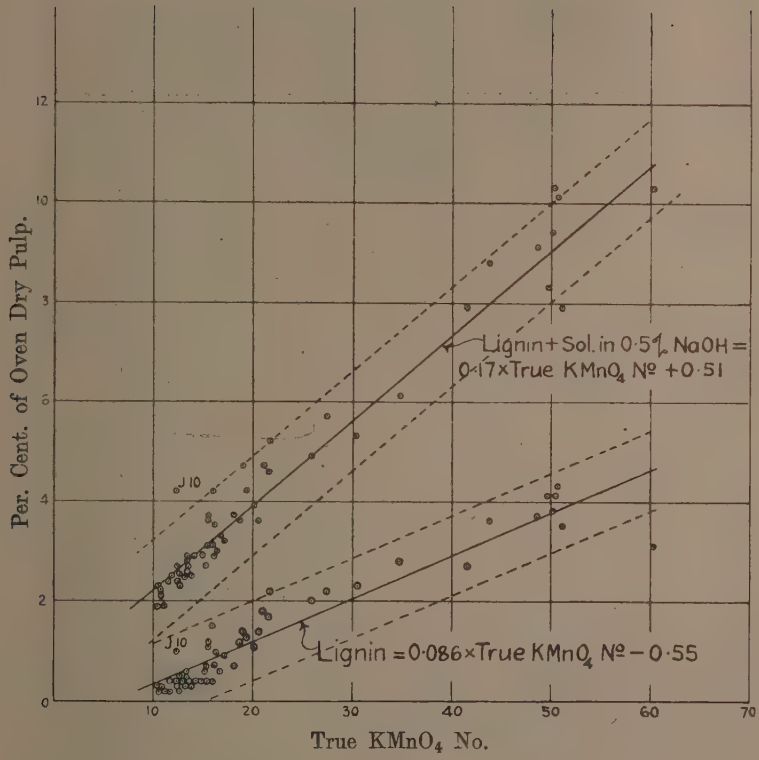

Per. Cent. of Oven Dry Pulp.
True $KMnO_4$ No.
Lignin + Sol. in 0·5% NaOH = 0·17 × True $KMnO_4$ No + 0·51
Lignin = 0·086 × True $KMnO_4$ No − 0·55
J 10
J 10
0
2
4
6
8
10
12
10
20
30
40
50
60
70

Fig. 6.

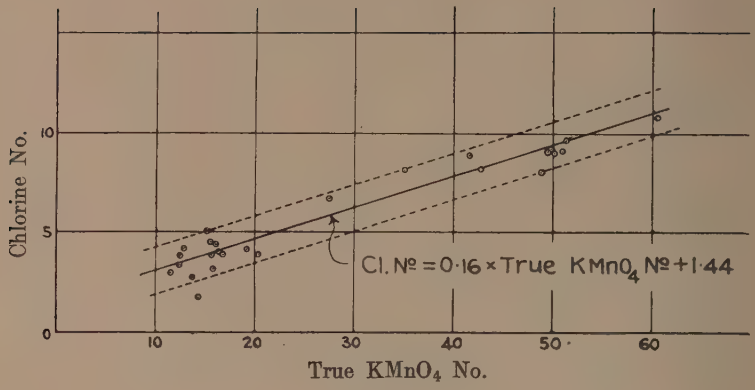

Chlorine No.
0
5
10
10
20
30
40
50
60
True KMnO4 No.
Cl. № = 0·16 × True KMnO4 № + 1·44

FIG. 7.

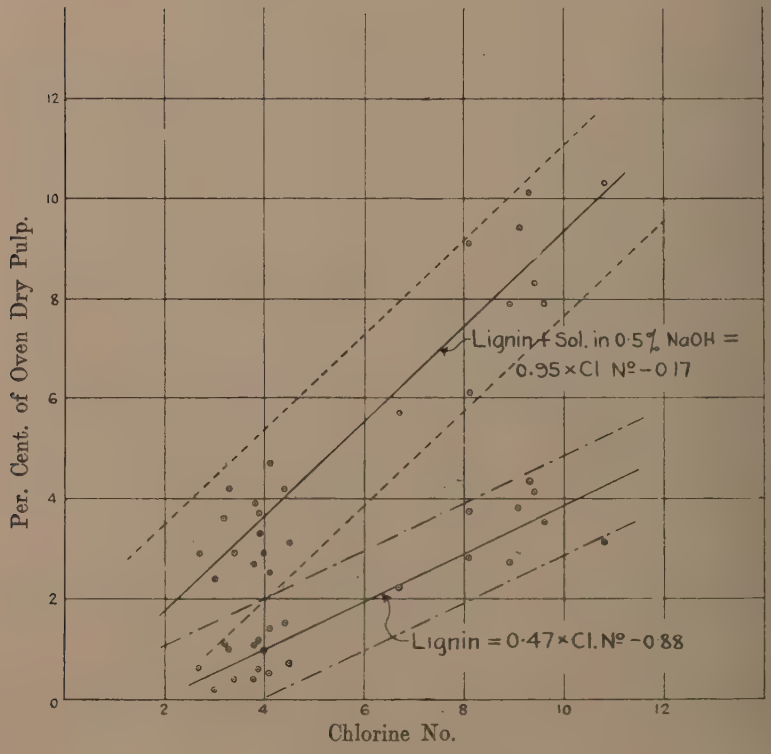

Per. Cent. of Oven Dry Pulp.
0
2
4
6
8
10
12
2
4
6
8
10
12
Chlorine No.
Lignin + Sol. in 0·5% NaOH =
0·95 × Cl № − 0·17
Lignin = 0·47 × Cl. № − 0·88

FIG. 8.

from the limits within which 95 per cent. of the points fall (Table 5) that the permanganate number provides a more accurate measure of both lignin and the sum of lignin and sodium hydroxide solubles than does chlorine number.

TABLE 5.

Dependent Variable.	Equation of Regression of Y on X. ($Y = a\ X + b$.)	Limits within which 95 per cent. of the points fall as a per cent. of O.D. cwt.	Figure in which Relationship is Plotted.
Lignin	Lignin (per cent. of O.D. wt.) = 0·086 × True $KMnO_4$ No. − 0·55 .. .. (1)	± 0·8	6
Lignin + Solubility in 0·5 per cent. Sodium Hydroxide	Lignin + Solubility in 0·5 per cent. NaOH (per cent. of O.D. wt.) = 0·17 × True $KMnO_4$ No. + 0·51 .. .. (2)	± 1·0	6
Chlorine Number..	Chlorine Number = 0·16 × True $KMnO_4$ No. + 1·44 .. (3)	± 1·1	7
Lignin	Lignin (per cent. of O.D. wt.) = 0·47 × Chlorine N. − 0·88 (4)	± 1·0	8
Lignin + Solubility in 0·5 per cent. Sodium Hydroxide	Lignin + Solubility in 0·5 per cent. NaOH (per cent. of O.D. wt.) = 0·95 × Chlorine No. − 0·17 .. .. (5)	± 1·7	8

(ii) It will be seen from Fig. 6 that, in the case of the lignin-permanganate number relation, the range within which 95 per cent. of the points fall is a much higher proportion of the estimated value than in the case of the sum of lignin and sodium hydroxide solubles-permanganate number relation. Consequently, the permanganate number provides a more accurate measure of the total non-carbohydrate material (as measured by the sum of lignin and sodium hydroxide solubles) than it does of the lignin value alone.

(iii) The close relationship between chlorine number and permanganate number (Fig. 7) indicates that a fundamentally similar reaction is the basis of each and affords some indication that further work may establish a relationship between permanganate number and bleachability.

Since the sum of lignin and sodium hydroxide solubles may be determined with an accuracy of ± 0.3 per cent., it is clear that these determinations cannot be replaced directly by means of permanganate number. At the same time the results show that some measure of these quantities is obtained, and for certain exploratory research purposes the determination will be satisfactory.

Throughout this work, the sum of lignin and sodium hydroxide extractives has been regarded as the total non-carbohydrate fraction of the pulp. That this is not strictly accurate is clearly recognized, since certain variable amounts of soluble or easily hydrolysed sugars are extracted by boiling 0.5 per cent. sodium hydroxide. In particular, pulp J10 (see Fig. 6) shows an abnormally high sodium hydroxide extractive value as compared with lignin and permanganate number and this may possibly be related to the fact that this pulp was somewhat degraded, having been prepared from a slightly decayed wood sample by rather drastic cooking treatment. It is possible, therefore, that the extraction of variable amounts of carbohydrates has resulted in an increased value for the standard error of the estimate, and it may be concluded that the permanganate number gives a satisfactory indication of the non-carbohydrate fraction of a pulp.

Summary.

1. The results show that permanganate number and chlorine number measure the sum of lignin and sodium hydroxide solubles rather than lignin alone.

2. The permanganate number may be determined more accurately than the chlorine number.

3. It is indicated that some of the variability in the relationship between permanagate number and the sum of lignin and sodium hydroxide solubles may be due to variation in the nature of the material extracted by sodium hydroxide.

4. The permanganate number determination supplies a rapid method of estimating degree of cooking but cannot satisfactorily replace the lignin determination except in cases where relatively wide limits are permissible.

Literature Cited.

1. Johnsen and Parsons.—*Paper Trade J.*, **76**: TS. p. 125, 1923.
2. Roe.—*J. Ind. Eng. Chem.*, **12**: 808, 1924.
3. Fahlstrom.—*Paper Trade J.*, **101**: Tappi, p. 301, 1935.
4. "Manual of Standard Testing Methods for Pulpwood, Pulp, Stuff, and Paper," U.S. Forest Products Laboratory, 1928.
5. Benjamin, L. R., and Somerville, J. L.—Coun. Sci. Ind. Res. (Aust.), Bull. 37, p. 26, 1928.
6.—Wiles.—*Paper Trade J.*., **98**: Tappi, p. 138, 1934.
7. Anon.—*Le papier*, June, 1937, p. 481.
8. Johansson.—*Paper Trade J.*, **101**: Tappi, p. 197, 1935.
9. Bergman.—*Pap. Fabr.*, **24**: 744, 1926.
10. Ritter, Seborg, and Mitchell.—*J. Ind. Eng. Chem.* (Anal. Ed.), 4: 202, 1932.
11. Kung.—*Pap. Fabr.*, **33**: 60-63, 1935.
12. Ezekiel.—"Methods of Correlation Analysis," p. 126, 1930.

PLATE 1.

(The Yield and Composition of a Mitchell Grass Pasture for a Period of Twelve Months. See Page 127).

FIG. 1.—Elderslie, Queensland. Typical channel country, Diamentina River, Elderslie.

[Photo. by J. F. Kennedy.

FIG. 2.—Elderslie, Queensland. Typical channel of Diamentina River, Elderslie.

[Photo. by J. F. Kennedy.

PLATE 2.

(The Yield and Composition of a Mitchell Grass Pasture for a Period of Twelve Months. See Page 127).

FIG. 1.—Elderslie, Queensland. Ironstone-Gidyea Ridge. October, 1935. Trees: Gidyea (*Acacia Cambodgei*). After summer rains carrying annual grass species, chiefly *Panicum* spp., *Sporobolus* spp., *Pappophorum nigricans*, and *Aristida ramosa*, together with pigweed (*Portulacea oleracea*).

[*Photo. by J. F. Kennedy.*

FIG. 2.—Elderslie, Queensland. Typical Bull Mitchell (*Astrebla squarrosa*) association in the open downs. Elderslie: April, 1936.

[*Photo. by J. F. Kennedy.*

PLATE 3.

(The Yield and Composition of a Mitchell Grass Pasture for a Period of Twelve Months. See Page 127).

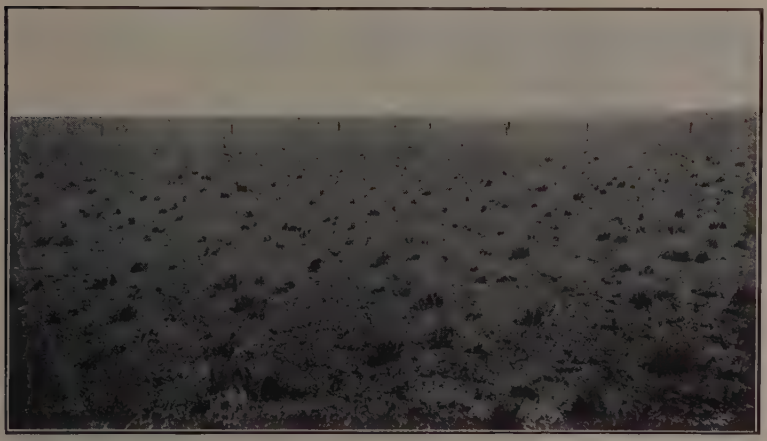


FIG. 1.—Elderslie, Queensland. Experimental area, November, 1935. Clumps are mainly *Astrebla squarrosa*.

[*Photo. by J. F. Kennedy.*

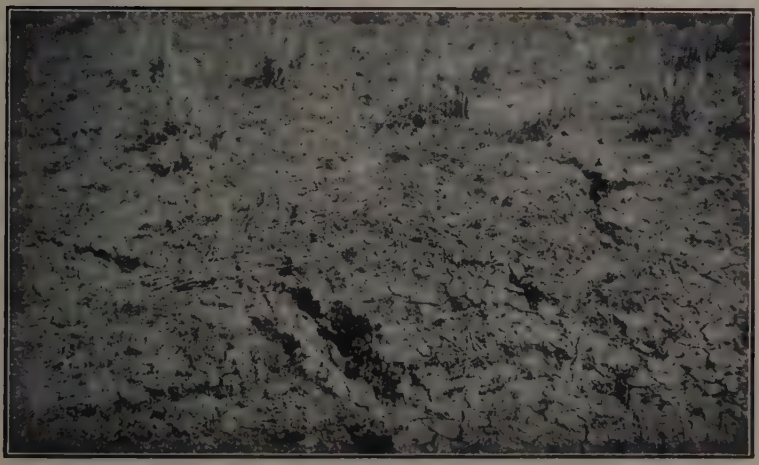


FIG. 2.—Elderslie, Queensland. Close up of grey ashy soil of open downs showing deep cracks in November, 1935 (after drought). Dry Bindyei (*Calotis hispidula*) in *left-hand* foreground. Clumps are mostly *Astrebla squarrosa*.

[*Photo. by J. F. Kennedy.*

PLATE 4.

(The Yield and Composition of a Mitchell Grass Pasture for a Period of Twelve Months. See Page 127).

FIG. 1.—Elderslie, Queensland. Experimental area in April, 1936. Identical photo. point as in Plate 3, Fig. 1. Chief species are : Bull Mitchell (*A. squarrosa*), Curly Mitchell (*A. pectinata*), *Panicum* spp.

[*Photo. by J. F. Kennedy.*

(The Sterilization of Fruit Cases. See Page 140).

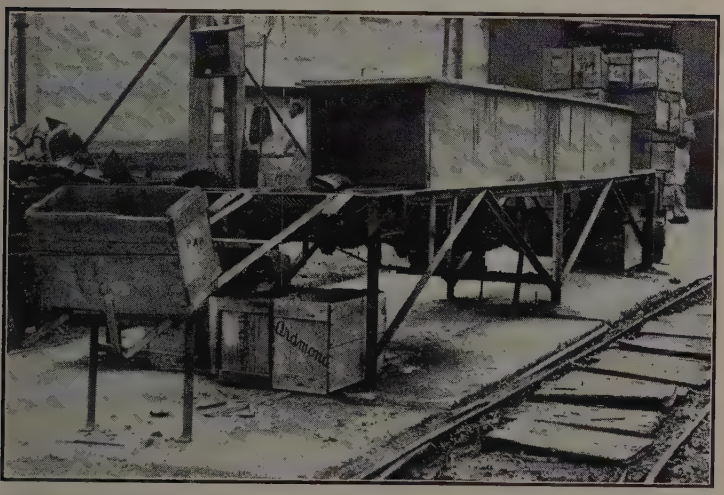


PLATE 6.

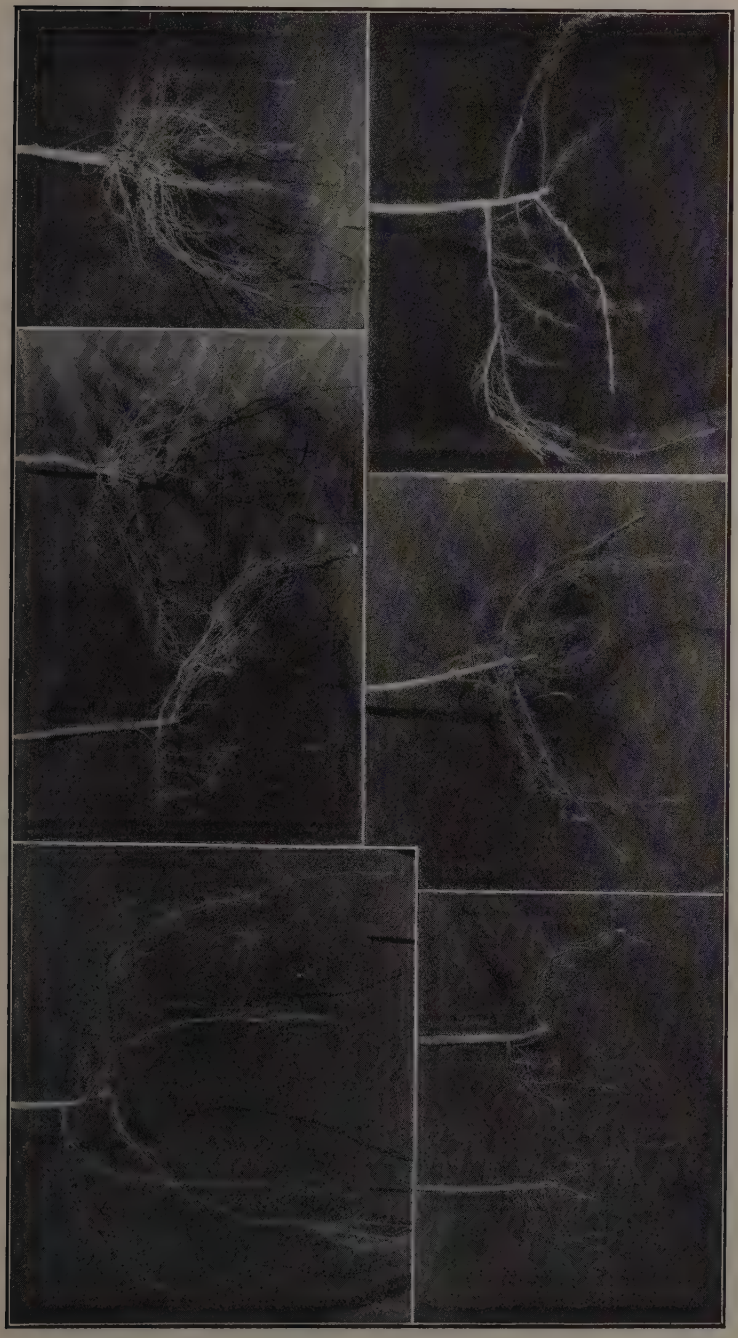
(Stock and Scion Investigations. See Page 169).

Photographs of the one-year-old root systems of various apple trees produced by layering methods. The trees were cut from the layer beds between 2nd July and 12th July. All subjects were photographed from the same distance.

1. (*Top*) Ben Davis. 2. (*Centre*) Hunsley's Seedling. 3. (*Bottom, left*) Allsopp's Early. 4. (*Bottom, right*) Delicious.

PLATE 7.

(Stock and Scion Investigations. See Page 169).



5. (*Top, left*) Winter Majetin. 6. (*Top, centre*) Jonathan. 7. (*Top, right*) Northern Spy. 8. (*Bottom, left*) Granny Smith.
9. (*Bottom, centre*) Niedwetzkyan. 10. (*Bottom, right*) Gravenstein.

Photograph of the M.S. "Warreen" taken during her trials, April, 1938. The turntable for the large purse-seine net can be seen at the stern. With this net in place and with the other equipment aboard, the stern would appear much lower in the water.

NOTES.

The Fisheries Investigation Vessel—The M.S. "Warreen".

In a previous issue (this *Journal,* **10**: 83, 1937) mention was made of a fisheries investigational vessel then under consideration for the Council's Fisheries Section. This vessel was completed in April, 1938, and has been named the *Warreen.* A photograph is reproduced in Plate 8 opposite.

This is the second fishery investigation vessel commissioned by the Commonwealth Government. The first, a steam trawler, F.I.S. *Endeavour,* carried out trawling investigations in Australian waters during the years 1909-1914. This work, which led to the discovery of valuable trawling grounds and to the establishment of an important trawling fleet, terminated with the tragic loss of the vessel and all hands in 1914.

The work of the *Endeavour* was confined to the investigation of demersal or bottom-dwelling fish, such as flathead. She was not equipped to study pelagic or the so-called "surface-swimming" fish such as the pilchard, barracouta, tunny or tuna, &c.

M.S. *Warreen* is designed and equipped to investigate both pelagic and demersal fish, at least to some extent. In other countries, for the capture of certain pelagic fish on a large scale, fishing gear of a type not hitherto used in Australia is employed; M.S. *Warreen* is specially designed to test some forms of this gear in Australian waters where certain pelagic fishes similar to those which are the basis of important industries overseas are known to occur.

A Danish seine net, hand-lines, and long-lines will be used for the capture of demersal fish, and dredges will be employed for the collection of shellfish such as scallops.

Warreen was built to Lloyds specifications by the Melbourne Harbor Trust Commissioners at Williamstown Dockyard. She follows closely in design a type of vessel used on the west coast of America known as a purse-seiner. The following is a brief description of her salient features:—

Dimensions.—Length over all 82 feet, breadth 19 feet, draft (mean) 8 ft. 6 in.

Hull Construction.—Steel to Lloyds specifications.

Engines.—Main—215 b.h.p. 2-cycle direct reversing Diesel. Auxiliary—28 b.h.p. 4-cycle Diesel. The main engine can be operated by remote controls from the upper and lower steering positions, also by ship's telegraph from the lower steering position to engine-room. Fuel capacity 4,500 gallons (which gives a range of some 2,000 miles).

Wireless Equipment.—Consists of two transmitters and receivers in one unit—a long wave for commercial work and a short wave for communication with aircraft. The approximate range (night-time) is 1,000 miles. A broadcast-receiver is also fitted with loud speaker extensions to certain parts of the vessel.

Depth Recording Apparatus.—One Echometer of the visual and recording type capable of measuring depths from 0 to 350 fathoms.

Life-saving Equipment.—Comprises one 16-ft. x 6-ft. lifeboat fitted with 7 b.h.p. petrol marine engine and one large skiff 18 feet x 8 feet. Both these boats are designed to assist fishing operations. The skiff is an essential feature of purse-seine operations.

Accommodation.—Permanent accommodation for thirteen persons and emergency accommodation for two persons have been provided.

Refrigeration and Fish Storage.—A small cork-insulated fish hold is provided for use with crushed ice. Two refrigerated cabinets have been fitted, one below deck and one in the laboratory.

Fishing Gear.—One Danish seine net for the capture of demersal fish; one purse-seine net 350 yards in circumference and 50 yards deep (this net, which is for the capture of pelagic fish, is carried on a large wooden turntable aft); one take-down wooden tank for carrying live bait for tuna fishing; live-bait fishing gear; hand-lines, trolling lines and long-lines (long-lines are set on the sea-bottom and are equipped with many baited hooks); harpoons and dredges. A crowsnest and observation platform has been fitted on the mainmast to assist fishing operations and navigation of the vessel.

Laboratory and Scientific Equipment.—A battery of special insulated bottles, lowered to different depths and then reversed, whereupon the temperatures at the different depths are automatically recorded and water-samples enclosed for subsequent analysis; a series of conical nets, standardized after those used on the various expeditions of S.S. *Discovery,* with size of opening and of mesh of net graded from large to small to collect large and small floating life (plankton) including fish eggs and young fish; drift bottles, for determining the main courses of surface currents in the sea; apparatus and chemicals for the analysis of sea water; various chemical reagents for preserving important materials in the collections and for preliminary treatment of tissues to be examined.

Some Flies Associated with Grasshoppers.

(Contributed by Miss M. E. Fuller, B.Sc., Division of Economic Entomology.)

Various flies have been bred from grasshoppers in the course of the Council's investigations of this pest. Three species have been described fully in papers which are being published in the Proceedings of the Linnean Society of New South Wales, and the present note is intended simply to give a brief account of their biology.

Trichopsidea oestracea.—This species belongs to the family Nemestrinidae, about the early stages of which very little is known in any part of the world, but all the species so far bred have been found to parasitise other insects. It attacks the plague hopper, *Chortoicetes terminifera,* and various other grasshoppers, and is widely distributed in eastern Australia. The amount of parasitism varies, being about 5 per cent. for all species attacked at Canberra. The larva lives in the abdomen of its host, only one being found in each parasitised hopper. When fully fed, it emerges from the still living hopper and enters the ground, where it remains as a prepupa for several months, pupating during the following summer. The pupal stage lasts about three weeks.

The larvae and pupae of *T. oestracea* were found to be somewhat similar to those of the European *Hirmoneura obscura,* which is parasitic on beetles, and is the only other Nemestrinid whose life history has been studied in detail.

Cyrtomorpha flaviscutellaris.—All Bombyliidae are parasitic, and numerous species have been listed by Uvarov (Locusts and Grasshoppers, London, 1928), as attacking grasshoppers in various parts of the world, but this is the only Australian member of the family whose early stages are known. The larvae were discovered by Dr. K. H. Key in egg-beds of *Austroicetes cruciata* at Nungarrin, Western Australia. They devour the eggs in the pods, being predatory rather than parasitic, and spend their prepupal stage amongst the empty pods. In the laboratory they remain as prepupae for several months, sometimes more than a year. The pupal stage occupied three weeks. The larvae and pupae were of the typical Bombyliid form and structure.

Helicobia australis.—This Sarcophagine species had been recorded as a grasshopper parasite, but careful field and laboratory experiments have proved that it is incapable of parasitism, and only deposits its maggots on the hoppers after they are dead. A vigorous and healthy culture was maintained on carrion for seven generations, and the larvae were found to be capable of producing a typical experimental strike on sheep. The life cycle is brief, the average for seven generations bred in one season being 30 days. They are typical Sarcophaga-like maggots, but have certain detailed morphological features setting them apart generically. The floor of the pharynx is ridged, which is a characteristic of saprophagous, as distinct from parasitic, maggots.

The Electrotechnical Journal of Japan.—A New English Edition.

The first number (dated June, 1937) of a new journal—the *Electrotechnical Journal*—published monthly in English by the Institute of Electrical Engineers of Japan has recently reached Australia.

The Institute, called the "Denki-Gakkwai" in Japan, was founded on 25th June, 1888. It has contributed greatly towards the remarkable progress that has taken place in Japan in the electrical field during the past half-century, and has always been an important factor in advancing the interests of its individual members and of the entire engineering profession in Japan.

The Institute publishes its official monthly organ in Japanese under the name *Denki-Gakkwai Zasshi,* approximately 9,000 copies per issue being printed. It contains 1,500 pages each year of the papers of highly professional and fundamental researches in applications in the electrical field.

Beginning with the June, 1937, issue, a new overseas edition in English is being published. This contains about 20 to 30 pages of the abstracts from papers in the home edition. Subscriptions to the English journal amount to 12 yen per year, and for single copies 1 yen. Members of the Institute residing in overseas countries are entitled to receive free of charge either the journal compiled in Japanese, or the overseas edition of the journal in English.

Co-operative Investigations in Wine-making.

The wine-making industry is nowadays quite an important one in Australia, the value of its total production having of late years reached the neighbourhood of £2,000,000.

Naturally the industry has encountered difficulties; in an effort to overcome some of them, it has been interested for some time past in scientific research. In 1934, the Australian Wine Board and the Waite Agricultural Research Institute of the University of Adelaide commenced some co-operative investigations into certain wine-making problems; in particular, "diseases" of sweet wines which are occasionally troublesome after export to London were studied. The lines of co-operation were that the Board financed an investigator, Mr. J. C. M. Fornachon, a graduate in Agricultural Science from the University of Adelaide, who was located at the Waite Institute where the University authorities afforded him accommodation and direction.

A considerable amount of success has already been obtained in this co-operative work. Mr. Fornachon, for instance, has been able to isolate the causal organism of the troublesome "disease" and to determine the conditions under which it flourishes. He is at present engaged on the investigation of the nature of the susceptibility of certain wines to the disease.

Arrangements have recently been completed with two other parties —the Federal Viticultural Council of Australia and the Council for Scientific and Industrial Research—to co-operate on a somewhat enlarged programme. As a preliminary, Mr. Fornachon has been appointed to a studentship under the Science and Industry Endowment Fund. He will leave Australia in about August, 1938, in order to spend two years abroad at locations where he will be able to obtain specialized experience. It is proposed that, in the first instance, he will proceed to California and ultimately return via France and Africa. On his return, he will continue at the Waite Institute where his investigations will again be financed by the Wine Board. In the meantime that Board is financing another investigator (Mr. F. H. Cooper, B.Ag.Sc.) who will carry on the present investigations at the Waite Institute.

A Committee representative of the four co-operating parties, and consisting of Professor J. A. Prescott (Chairman), (representing C.S.I.R.), Dr. A. E. Platt, Adelaide Hospital (representing the University of Adelaide), Mr. N. L. Salter (representing the Australian Wine Board), and Mr. T. M. Hardy (representing the Viticultural Council) has been set up in connexion with the work. This Committee is advising, *inter alia*, as to places Mr. Fornachon should visit whilst abroad.

Lectures to Architects and Woodworking Instructors.

As part of the plan of the Division of Forest Products to spread the results of its work as widely as possible, arrangements have now been completed for two sets of lectures.

The first course will be given by Mr. R. Ferguson to architectural students of the University of Sydney and will form part of their regular course of instruction. This series of lectures began in the latter part of April; the arrangements for them were made through Professor Wilkinson, the Dean of the Faculty of Architecture.

The second course is to be given to woodworking instructors in the Technical Schools attached to the Education Department of Victoria, and has been arranged through the Chief Inspector of Technical Schools, Mr. E. P. Eltham. There will be ten evening lectures given by various members of the staff of the Division.

On the 24th and 25th March, 1938, a number of maintenance officers of the State Electricity Commission were given a special short course on the preservation of timber by Mr. J. E. Cummins, Senior Preservation Officer, of the Division. The first day was spent in lectures in the Division and the second day in inspection of field stations. There has always been very close co-operation between the Division and the Commission, which gives an annual grant in support of the Division's work. The course proved of considerable benefit, and it is hoped to repeat it from time to time.

The Drying of English Ash for Sporting Goods.

Typical of the minor problems which are dealt with in the Division of Forest Products is one which recently arose in the drying of English ash for sporting goods.

It was found in practice that kiln drying darkened the colour of the ash sufficiently to spoil its appearance for tennis racquets and other sporting equipment. This discolouration militated considerably against the use of the dried timber—more from considerations of appearance than because of any reduction in mechanical strength. The tennis playing public apparently regarded the darker coloured wood as of inferior quality.

At this stage the problem was referred to the Division. Investigations soon showed the discolouration was not due to the temperatures used in the kilns but to the use of relatively high humidity during drying. Subsequent work, and comparison with controls which had been air-dried, showed that, for partially air-dried English ash at least, there were few, if any, undesirable effects, provided that a large wet bulb depression was maintained during the period in the kiln (equivalent to relative humidities as low as 30 to 40 per cent.). The allowable variation in temperature was between 110° and 140° Fah. Under these conditions, the timber can be successfully kiln dried free from the discolouration effects mentioned above.

Work on Citrus Fruit.—Recent Contributions.

The Council has recently received two helpful contributions towards the cost of its work on problems confronting the citrus industry.

One of these contributions comes from The Water Conservation and Irrigation Commission of New South Wales, which has advised that, in its estimates for the current year, it has made provision for reinstating its contribution to the Griffith Research Station to the original pre-depression amount of £1,500 per annum.

The other grant has been made by the Victorian Central Citrus Association Proprietary Limited. At the annual meeting of the shareholders of this body, held in February last, it was decided to make the Council a grant of £100 per annum for five years for the purpose of

assisting in further research on citrus problems. It is proposed to use the grant to meet part of the cost of physiological studies of the citrus tree.

Appointment of Dr. A. E. V. Richardson.

Dr. A. E. V. Richardson, who for many years past has been the Director of the Waite Agricultural Research Institute of the University of Adelaide, and who has also been a member of the Executive Committee of the Council for Scientific and Industrial Research since 1927, has now been appointed as Deputy Chief Executive Officer of the Council on a full-time basis.

Dr. Richardson will continue to be a member of the Executive Committee of the Council, and will be located at its head office in Melbourne. He took up his new duties on the 19th April.

Professor J. A. Prescott has been appointed by the University of Adelaide to take Dr. Richardson's place as Director of the Waite Institute. Professor Prescott will continue to act as the Chief of the Council's Division of Soils.

Recent Publications of the Council.

Since the last issue of this *Journal*, the following publications of the Council have been issued:—

Bulletin No. 115.—"A Soil Survey of Part of the Denmark Estate, Western Australia," by J. S. Hosking, M.Sc., A.I.C., and G. H. Burvill, B.Sc.(Agric.).

This publication gives the results of a soil survey undertaken jointly by the Department of Agriculture of South Australia and the Council's Division of Soils in order to provide a basis for the improvement of the agriculture of the district. The local problems are associated with the dairying industry, and include those of pasture production and the control of an enzootic wasting disease due to a deficiency of cobalt in the diet of the animals and thus related to the coast disease of South Australia and to bush sickness of New Zealand. The survey reveals the predominant association of the disease with one particular soil type, but even the better areas are under suspicion. Possibly a clue to the position from the point of view of the soil worker is to be found in the observation made by the Government Geologist (Mr. F. G. Forman) that the parent rock, a gneissic granite, appears to be singularly deficient in metal-bearing veins. The area surveyed is characterized vegetatively by karri, jarrah, marri, and moorland heath associations. Thirteen soil types, grouped in nine series, have been identified and named. They vary from true podsols with the well developed coffee rock or hardpan layer, through weakly podsolised types to types showing certain affinities to those of the red brown earths.

Bulletin No. 116.—"The Relation of Phosphate to the Development of Seeded Pasture on a Podsolised Sand," by H. C. Trumble, M.Agr.Sc., D.Sc., and C. M. Donald, B.Sc.Agr.

The establishment of seeded pastures in southern Australia depends largely on the improvement of the available phosphate content of the

soil, together with the seeding of suitable pasture legumes and the incorporation of permanent pasture grasses. The basic importance of the superphosphate-legume combination is most evident on the widespread soils of the podsolised type, which are extremely low in both available phosphate and available soil nitrogen. The results discussed in the Bulletin show that the dressings of superphosphate at present employed in the development of subterranean clover pastures can be considerably increased before maximum economic returns are likely to be realized. It is suggested that a dressing of at least 2 cwt. of superphosphate per acre be applied annually for the first three years.

Pamphlet No. 76.—"Grading Studies in 'Ash' Eucalypts (Division of Forest Products—Technical Paper No. 26)," by R. F. Turnbull, B.E., A. J. Thomas, Dip. For., I.F.A., and F. E. Hutchinson, B.Sc.F., B.For.Sc. In 1930, the Standards Association of Australia appointed a Committee, with Sub-committees in each of the States, to standardize grades in Australian timbers. Much of the actual investigational work involved is being carried out by the Division of Forest Products. The present publication covers the work on the ash group of eucalypts which are of great commercial importance. It is pointed out that, at the present time, grading practice lacks uniformity, and that the actual definition of grades varies between mills and consuming interests. The grading practised varies even more widely than the grade specifications. This is attributed to the fact that the grade prescriptions as originally drafted have proved unnecessarily stringent. The Pamphlet gives a new set of specifications which would maintain uniformity in use value with standards issued for mill products of other species, and would express the present practice that seems to be giving some satisfaction in the trade.

Section of Food Preservation and Transport.—Circular No. 2-*P.*—"Hygienic Methods for the Preparation of Beef in the Meatworks."

The purpose of this Circular is to set out in non-technical language the nature and sources of the microbial contamination of chilled beef intended for export from Australia to Great Britain, and also to indicate hygienic methods which may be adopted in the meatworks to reduce this contamination to small proportions. A detailed account of the investigations on which the Circular is based will probably be published in the Council's Bulletin series at a later date.

Forthcoming Publications of the Council.

At the present time the following future publications of the Council are in the press:—

Bulletin No. .—"A Soil Survey of the Horticultural Soils in the Murrumbidgee Irrigation Areas of New South Wales," by J. K. Taylor, B.A., M.Sc., and P. D. Hooper.

Bulletin No. .—"Some Effects of Green Manuring on Citrus Trees and on the Soil," by E. S. West, B.Sc., M.S.

Bulletin No. .—"The Regional and Seasonal Incidence of Grasshopper Plagues in Australia," by K. H. L. Key, M.Sc., Ph.D., D.I.C.

Bulletin No. .—"Observations on the Toxicity of Fluorine for Sheep," by A. W. Peirce, M.Sc.

Pamphlet No. .—"The Growth of Plants in a 'Coasty' Calcareous Sand, South Australia." Paper No. 1. Preliminary investigations on the effect of copper and other elements on the growth of plants in a "coasty" calcareous sand at Robe, South Australia, by D. S. Riceman, B.Ag.Sc., and C. M. Donald, B.Sc.Agr. Paper No. 2.—The occurrence of "reclamation disease" in cereals in South Australia, by C. S. Piper, M.Sc.

Pamphlet No. .—"A Study of Persistency, Productivity, and Palatability in some Introduced Pasture Grasses," by A. McTaggart, Ph.D.

Pamphlet No. .—"The Storage of Oranges with Special Reference to Locality, Maturity, Respiration, and Chemical Composition," by S. A. Trout, M.Sc., Ph.D., G. B. Tindale B.Agr.Sc. and F. E. Huelin, B.Sc., PhD.

Pamphlet No. .—"The Humidity of the Atmosphere and the Moisture Conditions within Mounds of *Eutermes exitiosus* Hill," by R. V. Fyfe, B.Sc.Agr., and F. J. Gay, B.Sc.

H. J. Green, Government Printer, Melbourne.

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